Vol. 17, No. 1 MARCH, 1960

THE QUEENSLAND JOURNAL OF AGRICULTURAL SCIENCE

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PUBLISHED QUARTERLY

By the Queensland Department of Agriculture and Stock, Brisbane

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FURTHER STUDIES ON THE CONTROL OF PRE-EMERGENCE ROT AND CROWN ROT OF PEANUTS

By G. S. PURSS, M.Sc.Agr.*

SUMMARY

Experiments with fungicidal seed dressings on peanuts conducted during the seasons 1955 to 1959 are described.

In laboratory tests there was a differential effect of fungicides on *Rhizopus* spp., *Aspergillus niger* and *Penicillium* spp. Organo-mercurials were very effective against *Rhizopus* spp. but not so effective against *A. niger* and *Penicillium* spp. Captan, thiram and chloranil were effective against *A. niger* and *Penicillium* spp. but not as consistently effective against *Rhizopus* spp. as the organo-mercurials.

Field trials demonstrated that, under certain conditions, organo-mercurials increased the incidence of crown rot caused by *A. niger*. A number of fungicides controlled pre-emergence rot but the organo-mercurials and captan were the most consistent. A combination of these two fungicides gave best control over both pre-emergence rot and crown rot.

Sowing rates could be profitably reduced to the recommended level, when reasonable control over crown rot can be expected.

I. INTRODUCTION

Two seedbed diseases of peanuts termed pre-emergence rot and crown rot are prevalent in Queensland and have been described previously (Morwood 1953). Pre-emergence rot causes decay of the seed before or just after germination and is usually caused by the pathogen *Rhizopus arrhizus* Fischer. Crown rot usually affects the plant soon after emergence and may be caused by a number of organisms, including *Aspergillus niger* van Tiegh., *Diplodia natalensis* Pole-Evans, *Rhizoctonia solani* Kuehn and *Sclerotium rolfsii* Sacc. Reference to crown rot in this paper is to the seedling disease caused by *A. niger,* the most commonly encountered pathogen. This fungus is also capable of causing a pre-emergence rot by attacking and killing the seedling prior to emergence.

Both these diseases occur elsewhere and considerable success has been achieved in their control by the use of fungicidal seed dressings. In general, the organo-mercurial compounds have been considered superior for the control of pre-emergence rot, although under some conditions non-mercurials are preferred

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(Gibson and Clinton 1953; Nema, Jain, and Asthana 1955; Wilson 1950; Tarr 1958). However, it has been found in East Africa that the use of organo-mercurials considerably increases the incidence of crown rot. Gibson (1953b) demonstrated that this effect is probably a result of the partial soil sterilization produced by these materials in the vicinity of the seed. Tolerant *A. niger* colonies are at an advantage under such conditions and can more readily attack the peanut seedling. He found no such effect with thiram, which gave good control of crown rot. On the other hand, it is reported that organo-mercurials still give good crown rot control in India (Nema, Jain, and Asthana 1955). In Queensland, control of both diseases by the use of organo-mercurial dressings has been reported previously (Morwood 1953) but the data presented indicate that it was by the control of pre-emergence rot that better plant stands were achieved. Despite the use of such dressings on all peanut seed sold in Queensland for many years, crown rot has continued to cause serious losses. For example, losses of up to 30 per cent. of plants were observed in the 1955-56 season, these being greater than any reported by Gibson (1953a) for East Africa.

This paper reports further experiments carried out to examine critically the effect of organo-mercurials on crown rot incidence in Queensland and to determine a seed dressing capable of giving control over both pre-emergence rot and crown rot.

II. EXPERIMENTAL METHODS

The effect of fungicidal seed dressings has been assessed under both laboratory and field conditions.

(a) Laboratory Tests

During laboratory germination tests of peanuts the growth of fungi seriously interferes with determination of germination percentage (Morwood 1953). Three groups of fungi predominate, namely *Rhizopus* spp., *Aspergillus niger* and *Penicillium* spp. Although the relationship of the seed-borne inoculum of *Rhizopus* spp. and *A. niger* to disease in the field is uncertain, the behaviour of a fungicide against these two fungal groups could conceivably act as a guide to its behaviour against pre-emergence rot and crown rot in the field.

In laboratory tests, treated seed was placed in germination trays between moist towelling. Fifty seeds were placed on each tray for each treatment and in most cases four replications were employed. The trays were placed in a constant temperature chamber (27°C) and after three days the percentage germination was determined. Fungal infections were classified into the three major groups previously mentioned. No seed carrying an infection was considered to have germinated and if more than one fungal type was present on a kernel each type was recorded.

(b) Field Trials

The ability of a fungicide to control pre-emergence rot was assessed by an accurate measurement of the percentage of seed which emerged from the soil as healthy seedlings. Crown rot control was assessed by observations and counts after emergence.

Field trials were carried out in three different ways.

(i.) *Hand-planted Trials.*—Furrows 3 ft. apart were opened up in moist soil. Plots were 1 chain long, in which length exactly 100 seeds were sown. Either four or six replications were employed.

(ii.) *Replicated Trials Sown with Normal Sowing Machinery.*—Either a 2-row or a 4-row planter was employed. Plots were 2 chains long and 2 rows wide except in one case, when the plots were 3½ chains long. The planters were fitted with normal peanut plates and the rate of sowing was calculated by weighings before and after sowing. In addition to emergence and crown rot determinations, yield figures were recorded in some trials.

(iii.) *Observation Plots.*—These were sown on properties to assess overall district behaviour of fungicidal seed dressings during the 1956-57 and 1957-58 seasons.

In all cases where statistical analysis has been required, transformed variates have been used.

III. MATERIALS

The fungicides studied were as follows:

1. *Captan (50% N-trichloromethylthio-tetrahydrophthalimide).
2. Captan A and B (Proprietary preparations containing 20% active ingredient).
3. Cerenox (10% quinoxyme benzoyl hydrazone).
4. Chloranil (98% tetrachloro-para-benzoquinone).
5. *Dichlone (50% 2,3-dichloro-1,4-naphthoquinone).
6. Organo-mercurials, "Harvesan", "Ceresan" and "Drisan" each 1.5% Hg; and "Agrosan" 1.0% Hg.
7. *P.C.N.B. (75% pentachloronitrobenzene).
8. Thiram (50% tetramethyl thiuram disulphide).
9. *Zineb (65% zinc ethylene bisdithiocarbamate).
10. *Ziram (76% zinc dimethyl dithiocarbamate).

* Wettable powder used in these cases. All other fungicides were prepared seed dressings.

Where mixtures of these fungicides were employed proportions were determined by weight and the fungicides thoroughly mixed by stirring and agitation in a jar.

Unless otherwise stated, all fungicides were added at a rate of 1 oz to 20 lb of seed. For small quantities the material was applied in glass jars which were agitated on rollers. For larger quantities the material was added to the seed in small bags and agitated by hand until a good cover was obtained. In the case of seed for field trials, treatment was carried out usually just prior to planting. In the 1957-58 season, planting was delayed for over three months after treatment owing to dry weather conditions.

The seed used was of the variety Virginia Bunch, which was machine-shelled. Each year seed samples being tested for germination by the Peanut Marketing Board were closely observed and a suitable grade selected. Careful attention was paid to fungal infections because it was considered desirable to use seed carrying relatively high infections of both *Rhizopus* spp. and *A. niger*. In the course of these observations it was noted that considerable variation occurred between grades in any year but more particularly between seed harvested in different seasons. In Table 1 the relative amounts of the two test fungi *Rhizopus* spp. and *A. niger* in the seasons under review are summarized.

Table 1

RELATIVE AMOUNTS OF FUNGAL GROUPS ON SEED PEANUTS AT KINGAROY

Season	*Rhizopus* spp.	*Aspergillus niger*
1955–56 ..	High	High
1956–57 ..	Low	Nil
1957–58 ..	Very high	Very high
1958–59 ..	Low	Very low

It is evident that it has been impossible to select seed over the years having similar amounts of fungi infection.

IV. SUMMARY OF 1955–56 EXPERIMENTS

During the 1955-56 season, laboratory tests on germination trays and hand-planted field trials were carried out. Results appear in Table 2.

These results show the effectiveness of organo-mercurial compounds against *Rhizopus* spp. and their relative ineffectiveness against *A. niger*. Thiram, captan and chloranil had the opposite effect. Under field conditions all treatments gave a significantly better emergence than the untreated. Crown rot was significantly higher with the organo-mercurial compounds.

Table 2

LABORATORY AND FIELD TESTS OF TREATED PEANUT KERNELS, SHOWING GERMINATION, PERCENTAGE SEED INFECTED, FIELD EMERGENCE AND CROWN ROT INCIDENCE DURING 1955–56 SEASON

Treatment	Laboratory Tests			Field Trials	
	Germination (equiv. %)	Seed Infected		Emergence (equiv. %)	Crown Rot (equiv. %)
		A. niger (equiv. %)	*Rhizopus* spp. (equiv. %)		
1. " Harvesan " ..	77·7	3·6	1·8	53·0	13·7
2. " Ceresan " ..	71·3	4·0	4·8	49·4	18·0
3. Thiram ..	70·8	0·3	6·6	45·2	7·8
4. Chloranil ..	68·7	0·3	9·4	47·7	5·2
5. Captan ..	67·6	0·1	9·2	49·8	5·3
6. Ziram	65·8	1·1	11·0	41·0	10·3
7. Zineb	57·7	0·8	16·9	32·0	10·4
8. Untreated ..	27·9	2·3	17·1	27·4	8·4
Significant differences ..	1 ≫ 5–8 2–4 ≫ 7, 8 5–7 ≫ 8 1 > 4 ; 5, 6 > 7	5 ≪ 1, 2 3, 4 ≪ 2 5 < 8 3, 4 < 1 7 < 2	1 ≪ 4–8 2, 3 ≪ 7, 8 1 < 3 ; 2 < 6 4, 5 < 7, 8	1 ≫ 3, 6–8 2, 5 ≫ 6–8 3, 4, 6 ≫ 7, 8 4 > 6	4, 5 ≪ 1, 2, 6, 7 3 ≪ 1, 2 6–8 ≪ 2 8 < 1

V. SUMMARY OF 1956–57 EXPERIMENTS

A machine-planted trial was repeated on two farms. At one locality (Crawford) the soil was in poor physical condition, having been cropped to peanuts for many years with very little crop rotation. At the other site (Kumbia)

Table 3

EMERGENCE, CROWN ROT AND YIELD PER PLOT FROM PEANUT SEED TREATED WITH DIFFERENT FUNGICIDES IN FIELD TRIALS AT KUMBIA AND CRAWFORD, 1956–57 SEASON

Treatment	Kumbia			Crawford		
	Mean Germination	Crown Rot (mean %)	Mean Yield (lb/plot)	Mean Germination	Crown Rot (equiv. %)	Mean Yield (lb/plot)
1. " Harvesan "	500	2·0	53·6	288	6·4	20·6
2. " Ceresan " ..	550	0·7	56·2	301	5·7	21·4
3. Captan ..	568	0·5	57·9	285	0·8	21·1
4. Thiram ..	574	0·7	55·0	291	2·5	22·2
5. Chloranil ..	540	0·5	59·4	258	1·4	22·9
6. Untreated ..	415	0·7	52·6	170	1·9	18·4
Significant differences ..	2–5 ≫ 6	Not analysed	5 > 1, 6	1–5 ≫ 6	3, 5 ≪ 1, 2 6 < 1, 2 4 < 1	5 ≫ 6 4 > 6

the soil was in good physical condition and crop rotation had been judiciously carried out for years. The rate of planting at both trials was 32 lb per acre. The plots at Kumbia were 1½ chains longer than the standard 2 chains. Results appear in Table 3.

These results demonstrate the suitability of the first four fungicides in assuring good emergence. The organo-mercurials again induced more crown rot under conditions where this disease was prevalent. Captan again showed the lowest incidence of crown rot. In Figure 1 adjacent plots at Crawford of untreated seed and seed treated with an organo-mercurial illustrate the differences in the resulting stand.

Fig. 1.—Seed treatment trial, Crawford, 1956-57 season. Left: two rows untreated. Right: treated with "Harvesan."

The effect of crown rot on a peanut stand is shown again in Figure 2, which is taken from observation plots at Wondai. The captan plot, in which 0·9 per cent. crown rot occurred, shows unbroken rows, while the organo-mercurial plot with 18 per cent. crown rot has many large gaps.

Because of the apparent differential effect on the different fungal groups, it was considered that combinations of the organo-mercurials with captan, chloranil and thiram would be worth investigating. These and a number of fungicides hitherto untried were included in a hand-planted trial, the results of which appear in Table 4. Crown rot incidence was negligible and is not included.

While the absence of crown rot reduces the value of these results, it is clear that the mixtures of organo-mercurials and captan, chloranil and thiram had no deleterious effect on germination. Although the germination of dichlone-treated seed was satisfactory, it was noted that an abnormal amount of bacterial growth occurred on germination trays.

Fig. 2.—Observation plots, Wondai, 1956-57 season. Plot on the left treated with captan, that on the right with "Ceresan."

Table 4

GERMINATION OF TREATED PEANUT KERNELS IN HAND-PLANTED TRIAL, 1956–57 SEASON

Treatment	Germination (equiv. %)
1. Captan	90·9
2. " Ceresan "/Captan 1 : 1	90·9
3. " Harvesan "/Captan 1 : 1	90·7
4. " Drisan "	90·2
5. " Ceresan "/Chloranil 1 : 1	89·3
6. " Harvesan "/Chloranil 1 : 1 ..	88·9
7. Dichlone	86·8
8. Chloranil	84·1
9. Thiram	83·4
10. " Ceresan "	79·8
11. " Ceresan "/Thiram 1 : 1	79·1
12. " Harvesan "/Thiram 1 : 1 ..	77·1
13. " Harvesan "	75·8
14. " Agrosan "	75·8
15. Cerenox	70·9
16. Untreated	70·1
Significant differences	1, 2 » 12–16 » 10, 11 3, 4 » 13–16 » 10–12 5–7 » 15, 16 5, 6 » 12–14 8, 9 » 15, 16

VI. SUMMARY OF 1957–58 EXPERIMENTS

Initial work was done in the laboratory, where tests were carried out to determine the limit to which captan in the organo-mercurial/captan mixture could be reduced and still give control over *A. niger* on the seed. Results appear in Table 5.

Table 5

COMPARISON OF GERMINATION AND FUNGAL INFECTION OF PEANUT SEED TREATED WITH ORGANO-MERCURIAL/CAPTAN MIXTURES IN LABORATORY TESTS, 1957–58

Treatment	Germination (%)	Percentage Kernels Infected with Fungal Colonies		
		Rhizopus spp.	*Aspergillus niger*	*Penicillium* spp.
Untreated	31	33	14	39
" Ceresan "	73	5	13	20
Captan	74	12	..	1
" Ceresan "/Captan 1 : 5	79	11	..	..
" Ceresan "/Captan 1 : 2	67	13	..	2
" Ceresan "/Captan 1 : 1	78	10	..	..
" Ceresan "/Captan 2 : 1	75	10	..	..
" Ceresan "/Captan 3 : 1	83	11	..	..
" Ceresan "/Captan 5 : 1	87	7	..	1
" Ceresan "/Captan 6·5 : 1	82	8	0·25	4·5
" Ceresan "/Captan 9 : 1	84	8	0·50	4·0
" Ceresan "/Captan 14 : 1	79	6	5·5	6·5
" Ceresan "/Captan 29 : 1	77	7	5·0	11·0

Table 6

EMERGENCE, YIELD AND CROWN ROT MEANS IN A MACHINE–PLANTED TRIAL OF TREATED PEANUT SEED AT KINGAROY, 1957–58 SEASON

Treatment	Emergence	Yield (lb/plot)	Crown Rot (%)
1. " Ceresan "/Captan 5 : 1	304	23·5	2·7
2. Captan	280	21·4	1·2
3. " Ceresan "	242	18·8	24·1
4. Thiram	234	18·7	2·6
5. Chloranil	225	19·7	0·4
6. Untreated	96	13·8	6·5
s. e.	13·4	1·20	
Necessary differences for significance 5%	40	3·6	Not analysed
Necessary differences for significance 1%	56	5·0	Not analysed
Significant differences ..	1 » 3–6 2–5 » 6 2 > 3, 4	1, 2, 4 » 6 1 > 3, 4, 5 3, 5 > 6	" Ceresan " obviously > all others

These results bring out clearly the differential effect on the fungal groups of the organo-mercurials and captan. *Penicillium* spp. apparently have the same general reaction to fungicides as *A. niger*. The combination of the two dusts in the right proportion achieves the best results.

The combination 5:1 was selected for use in the machine-planted field trial, which was planted at Kingaroy on light gravelly soil where crown rot had been a problem in previous years. Results appear in Table 6. Rate of planting in this trial was 42 lb per acre.

Under these conditions captan was superior to organo-mercurials. A mixture of the two gave outstanding results both in emergence and in yield. Crown rot incidence was slightly greater than with captan straight. Thiram was inferior to captan in all respects.

In a hand-planted trial on two sites, various untested materials and combinations of organo-mercurials with captan and thiram were compared.

Table 7

EMERGENCE AND CROWN ROT INCIDENCE IN HAND-PLANTED PEANUT TRIALS AT KINGAROY AND KUMBIA, 1957–58

Treatment	Kingaroy				Kumbia		
	Emergence		Crown Rot		Emergence		Crown Rot (mean %)
	ϕ	Equiv. %	ϕ	Equiv. %	ϕ	Equiv. %	
1. "Agrosan"	51·7	61·6	16·6	8·2	52·0	62·1	2·5
2. "Ceresan"	49·4	57·7	16·9	8·5	47·7	54·8	4·75
3. "Drisan"	49·6	58·0	13·7	5·6	47·5	54·3	3·75
4. P.C.N.B.	50·4	59·3	15·3	7·0	47·2	53·8	1·75
5. Captan	46·3	52·3	1·4	0·1	41·8	44·5	1·25
6. Captan A (20%) ..	42·4	45·4	6·8	1·4	39·2	39·9	0·50
7. Captan B (20%) ..	44·1	48·5	6·8	1·4	41·2	43·4	0·75
8. Thiram	42·5	45·7	7·0	1·5	45·1	50·2	0·75
9. Chloranil	37·2	36·6	7·0	1·5	33·5	30·5	0·25
10. "Ceresan"/Captan 1 : 1	47·9	55·0	7·5	1·7	43·4	47·2	0·25
11. "Ceresan"/Captan 2 : 1	49·7	58·1	3·5	0·4	47·9	55·0	0·25
12. "Ceresan"/Captan 5 : 1	49·2	57·4	8·7	2·3	42·8	46·2	0
13. "Ceresan"/Thiram 1 : 1	48·3	55·8	10·6	3·4	44·6	49·2	0·75
14. "Ceresan"/Thiram 2 : 1	51·2	60·8	10·5	3·3	45·3	50·5	0·75
15. "Ceresan"/Thiram 5 : 1	50·2	59·1	11·4	3·9	43·7	47·8	1·0
16. Untreated	27·3	21·0	8·7	2·3	32·6	29·0	1·25
Necessary differences for significance 5%	4·5		5·1		4·7		Not analysed
Necessary differences for significance 1%	6·0		6·8		6·2		

Results appear in Table 7. The plots at Kingaroy were on a poor gravelly loam, while at Kumbia a good scrub soil was used.

These results show the organo-mercurials as slightly superior to captan for pre-emergence control. The combined treatments all show better crown rot control than the organo-mercurials, although the captan combinations are better than the thiram combinations in this regard. The performance of P.C.N.B. is interesting in that its effect on crown rot is similar to that of the organo-mercurials, causing an actual increase in disease over untreated seed. The effect of site is also emphasized. A reduction to a 20 per cent. concentration of captan reduces the advantageous effect of this fungicide.

In co-operation with the Peanut Marketing Board, observation plots were planted on various properties during the season. Three grades of seed each treated with "Ceresan," captan and a mixture of these two fungicides were compared. Each grade was sown on two different properties with each treatment replicated twice on each farm. These plots were sown as part of the general commercial crop by the growers concerned and were of variable size. Disease determinations were made on small areas, 2 chains long and 4 rows wide, within the larger plots. Only one count of plants affected with crown rot was made two weeks after the initial emergence count. Results appear in Table 8.

Table 8

EMERGENCE AND CROWN ROT MEANS IN THREE GRADES OF SEED TREATED WITH DIFFERENT FUNGICIDES AND SOWN ON DIFFERENT FARMS, 1957–58

Grade	"Ceresan"		Captan		"Ceresan"/Captan	
	Emergence	Crown Rot	Emergence	Crown Rot	Emergence	Crown Rot
1 ..	483	42	485	3	554	4
2 ..	442	28	419	1	508	3
3 ..	560	18	549	1	582	2
Mean ..	495	29	484	2	548	3

These results indicate that over a range of soil types and seed grade a combination dust of an organo-mercurial and captan gives the best results. Emergence figures show little difference between the organo-mercurials and captan.

VII. SUMMARY OF 1958–59 EXPERIMENTS

A machine-planted trial was conducted comparing two combinations of captan with organo-mercurials having a 1 per cent. and 1·5 per cent. Hg content. The seed used carried no apparent *Aspergillus niger* and the rate of planting was 42 lb per acre. Results appear in Table 9.

Little difference was shown between any of the combined seed dressings in control of pre-emergence and crown rot. It is interesting to note that although there are no significant differences in yield, the combined seed dressings and captan are all superior to the organo-mercurial in this regard.

Table 9

Comparison of the Control of Pre-emergence and Crown Rot of Peanuts by Various Fungicidal Combinations in a Machine-planted Trial, 1958–59 Season

Treatment	Mean Emergence	Crown Rot		Mean Yield (lb per plot)
		ϕ	Equiv. %	
1. Captan	360	11·4	3·9	18·9
2. "Agrosan"/Captan 2 : 1	363	11·9	4·2	18·8
3. "Agrosan"/Captan 5 : 1	383	12·2	4·5	19·8
4. "Ceresan"/Captan 5 : 1	371	12·4	4·6	20·2
5. "Ceresan"/Captan 2 : 1	362	12·9	5·0	21·4
6. Untreated	322	18·5	10·0	17·4
7. "Agrosan" (1·0% Hg)	358	25·4	18·4	17·3
8. "Ceresan" (1·5% Hg)	377	27·2	20·9	15·4
s. e.	10·8	1·39		1·77
Necessary differences for significance 5%	31·8	4·1		
Necessary differences for significance 1%	43·3	5·6		
Significant differences	3, 8, 4 » 6	1–4 « 6–8		No sig. diff.
	2, 5, 1, 7 > 6	5, 6 « 7, 8		
		5 < 6		

During this season a machine-planted trial was done comparing different seed lines for disease incidence. These lines were each treated with captan, "Agrosan" and a mixture of these two. Results appear in Table 10.

It can be noted that the emergences in the organo-mercurial and combined dust treatments are significantly better than in the captan treatment, which in turn is better than the untreated. Crown rot in the organo-mercurial plots is significantly greater than in all the others, including the untreated, while there is little difference in the effect of captan and the combined dust treatments on this disease.

Table 10

COMPARISON OF EMERGENCE AND CROWN ROT MEANS IN DIFFERENT SEED LINES OF PEANUTS TREATED WITH FUNGICIDAL DRESSINGS, 1958–59 SEASON

Grade	Emergence (equiv. %)					Crown Rot (equiv. %)				
	Untreated	"Agrosan"	Captan	"Agrosan"/Captan	Mean	Untreated	"Agrosan"	Captan	"Agrosan"/Captan	Mean
69 ..	53·3	63·0	54·5	68·2	59·8	0·8	4·6	0·5	0·1	1·1
Ath. 28 ..	29·9	59·2	48·4	63·0	50·0	1·0	7·0	0·2	1·8	1·8
107 ..	52·5	72·7	67·5	72·7	66·6	2·8	2·9	0·0	0·6	1·2
115 ..	59·3	74·5	68·4	76·2	69·8	1·5	4·2	0·9	0·3	1·5
Mean	48·6	67·5	59·8	70·2		1·5	4·6	0·3	0·6	
Significant differences	Grades :—107, 115 » 69 » Ath. 28 Fungicides :—"Agrosan," "Agrosan"/Captan » Captan » Untreated					Grades :—No significant differences Fungicides :—Captan « Untreated, "Agrosan" "Agrosan"/Captan « "Agrosan" "Agrosan"/Captan < Untreated Untreated « "Agrosan"				

VIII. DISCUSSION

It is clear from laboratory tests that *Aspergillus niger* and *Penicillium* spp. possess greater tolerance to organo-mercurial compounds than *Rhizopus* spp. Under field conditions there is an increased incidence of crown rot, caused by *A. niger,* when such compounds are used as seed dressings. These findings confirm those previously reported for East Africa (Gibson 1953b). In some cases this effect is very pronounced, as in the machine-planted trial of 1957-58 when crown rot affected 24·1 per cent. of the plants in the organo-mercurial treatment and only 6·5 per cent. of the plants from untreated seed. It is not implied that all seed treated with these fungicides will suffer severely from crown rot. Other conditions, particularly those of soil type, cropping history and seed damage, play an important role in the incidence of the disease, as has already been pointed out by Morwood (1953). The use of organo-mercurial compounds accentuate the disease when it is prevalent. It is likely that P.C.N.B. has a similar effect, as revealed in the hand-planted trial of 1957-58. Other fungicides, such as captan, thiram and chloranil, give good control of crown rot when used as seed dressings, though thiram is slightly inferior to the other two. A concentration of 20 per cent. captan gives inferior results to a 50 per cent. dust, which is the highest concentration available in Australia.

Pre-emergence rot is controlled by a number of fungicides but the organo-mercurials and captan appear to behave consistently better than the other compounds. It is interesting to observe that under some conditions organo-mercurials give better emergence while in other cases captan is superior. This appears to bear out the findings in the United States of America with regard to specificity of fungicides and variation of results from year to year with different treatments (Wilson 1950). These differences could possibly be explained by the differential effect of the two fungicides on *Rhizopus* spp. and *A. niger* and differences in the relative abundance of these organisms.

It is evident that a combined dust of organo-mercurial and captan achieves the most consistent results. In all trials incorporating this treatment, at least one combination of the two fungicides gave outstanding control of pre-emergence rot and crown rot. While the combinations of organo-mercurials with thiram were good for pre-emergence rot, they were slightly inferior to the combinations with captan for crown rot control. Captan used as a straight dressing was slightly superior to any of the combinations for crown rot control, but the differences were negligible.

The proportion of 50 per cent. captan can be reduced to as low as one part to five of organo-mercurial and still give good control of crown rot.

The effect of plant stand on yield is confusing. This relationship, of course, depends largely on weather conditions experienced throughout the growing season. In these trials significant differences between different fungicides were obtained in only one year despite rather large differences in plant stands. It is obvious from these limited trials that increasing plant stands beyond a certain point does not

result in increased yield. It is a fact, however, that most growers plant much more than the recommended 30 lb per acre in order to compensate for possible crown rot losses (Kerr and Cartmill 1951).

IX. CONCLUSIONS

The use of straight organo-mercurial compounds on peanut seed should be avoided because of the increase in crown rot often associated with this practice.

Seed dressings of captan and thiram could be used to advantage and of these two captan is preferred because of its slightly better control of crown rot. It is possible that a captan preparation in excess of 50 per cent. active ingredient would be even more effective if such was available on the Australian market.

The ideal seed dressing is one incorporating both an organo-mercurial and captan. Although 1 part in 5 is satisfactory it is felt that a 1:2 combination would give additional protection under conditions very favourable to crown rot.

The immediate value of an improved seed dressing which ensures reasonable control of crown rot would be to reduce the seeding rates down to the recommended level and give even, unbroken stands.

X. ACKNOWLEDGEMENTS

The Peanut Marketing Board gave considerable assistance in the conduct of these experiments by providing seed and facilities. Many growers allowed trials to be planted on their properties, often at considerable inconvenience. Officers of the Agriculture Branch and the Field Officer of the Peanut Marketing Board assisted in the conduct of the experiments. The statistical analyses were carried out by Mr. P. B. McGovern, Senior Biometrician in the Department. All this assistance is gratefully acknowledged.

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(Received for publication September 21, 1959)

SPECIES OF *PYTHIUM* IN QUEENSLAND

By D. S. TEAKLE, B.Agr.Sc.*

SUMMARY

Fourteen species of *Pythium* have been recorded in Queensland. Notes are given on the morphological and cultural characters found useful in identifying these species.

Growth-temperature studies confirm that maximum temperature can be used as an aid to morphology in identification.

An annotated host index for Queensland is presented.

I. INTRODUCTION

During the investigation of some root diseases in Queensland, it became apparent that more species of *Pythium* were present than had previously been recorded for this State. Prior to the commencement of this investigation in 1954, three species of *Pythium* had been recognised. *Pythium ultimum* Trow was recorded from root and trunk rot of papaw (Simmonds 1937), *P. aphanidermatum* (Eds.) Fitzp. from transport rot of beans (Simmonds 1950), and *P. periilum* Drechsl. from root rot of sugar-cane (unpublished records, Queensland Bureau of Sugar Experiment Stations, Brisbane).

The present paper deals with the more recent work on identifying members of this genus, as a result of which a further 11 species have been added to the list and the host range greatly extended.

II. PROCEDURE

Isolates were identified in the light of the monograph on the genus *Pythium* by Middleton (1943). Descriptions in this paper are therefore limited to growth-temperature relations (Table 1), a summary of the morphological dimensions of the oogonia and oospores (Table 2), and notes setting out the main characters used in distinguishing the species studied.

To ensure that the material used in identification was as genetically pure as possible, all cultures obtained were subjected to hyphal tip subculturing. Hyphal tips were grown on potato-dextrose agar, on which all cultures grew well and best displayed their growth-habit characteristics. Photographs illustrating the several growth habits encountered are given in Figure 1.

Most isolates produced sexual and asexual reproductive organs in 3-20 days when grown on water agar, potato-dextrose agar, and cornmeal agar. With isolates reticent in forming reproductive bodies, special treatment was often necessary. In these cases recourse was made to original descriptions of species and to Middleton's

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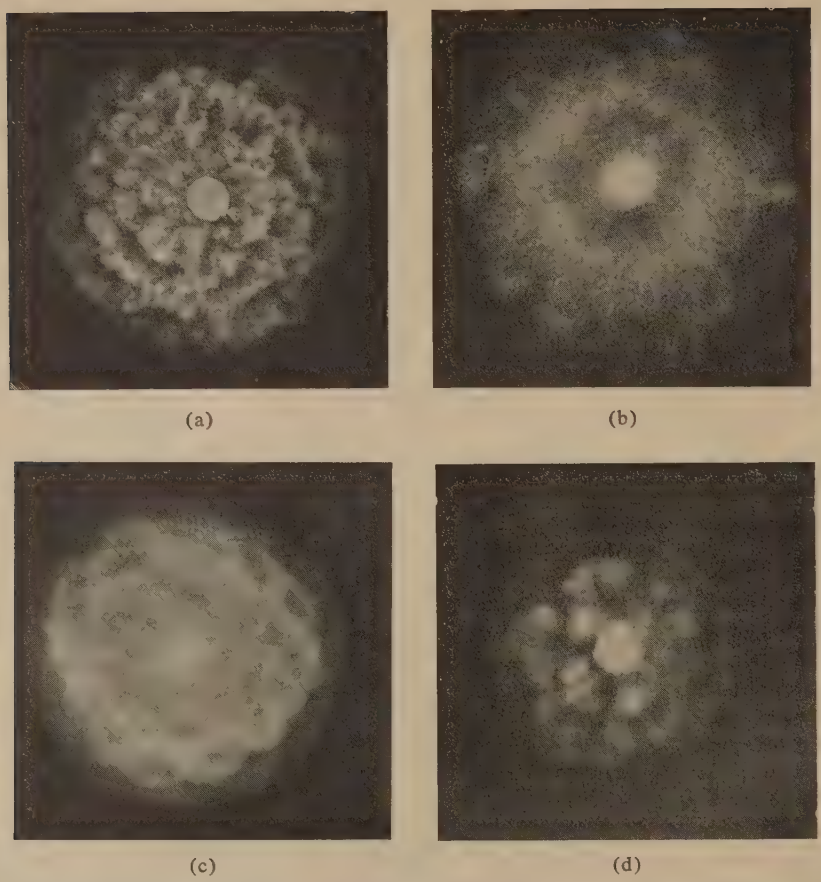

Fig. 1.—Growth habits of species of *Pythium*. One to two days on potato-dextrose agar. (a) *Pythium acanthicum*—cumulous-rosette; (b) *Pythium aphanidermatum*—arachnoid; (c) *Pythium torulosum*—rosette; (d) *Pythium vexans*—rosette.

monograph for appropriate techniques. Even so, some isolates failed to produce either their sexual or asexual fruiting bodies; few isolates could be induced to form zoospores. Fortunately, in many of these incompletely studied isolates, indentification was possible from certain distinctive characters.

III. GROWTH–TEMPERATURE RELATIONS

Middleton (1943) found growth-temperature relations to be a valuable adjunct to morphological characteristics in specific identification. He found that the behaviour of conspecific isolates was most uniform at their upper temperature limit; the minimum and optimum values were more variable.

Table 1

MYCELIAL GROWTH OF PYTHIUM SPP. ON CORNMEAL AGAR AT VARIOUS TEMPERATURES
Average Growth in Millimeters over 24-hour Period

Organism	Temperature (°C)																			
	6	8	11	12·5	14	15·5	17·5	19	20·5	22	23·5	25·5	27	28·5	30·5	32	34·5	36·5	38·5	43·5
P. acanthicum ..	t	1	4	..	7	9	11	14	..	15	17	21	22	23	25	24	24	18	4	0
P. aphanidermatum ..	0	0	3	..	7	12	15	19	22	25	27	33	34	37	43	48	51	48	36	1
P. debaryanum ..	t	4	11	12	13	18	20	..	23	26	29	31	28	32	34	30	6	t	0	0
P. dissotocum ..	1	5	8	10	13	16	18	21	23	25	29	31	31	34	34	28	8	2	t	0
P. helicoides	0	t	3	5	8	12	14	18	19	22	24	25	31	32	38	35	35	32	14	1
P. irregulare	5	9	11	15	..	17	20	22	24	28	29	29	29	31	30	24	14	1	0	0
P. myriotylum ..	0	1	4	6	8	9	14	18	21	24	28	30	39	38	43	46	49	47	24	1
P. oligandrum ..	0	0	4	7	11	14	16	20	22	23	25	31	34	36	40	35	33	13	t	0
P. periilum	2	5	6	..	8	9	10	11	..	11	12	14	15	15	14	12	8	2	t	0
P. spinosum	4	8	13	..	14	20	22	24	..	28	28	31	32	31	28	12	3	1	0	0
P. splendens	1	3	9	13	..	18	23	29	35	37	39	45	51	49	49	35	25	2	0	0
P. torulosum	t	3	4	..	5	6	7	8	..	10	10	11	13	13	14	14	13	6	1	0
P. ultimum	2	6	10	..	15	19	20	26	..	29	..	32	33	35	35	31	8	2	1	0
P. vexans	t	1	1	..	3	7	11	13	..	16	18	19	19	20	19	4	2	t	0	0

t = trace.

In Queensland, growth-temperature studies were carried out with one or more isolates of each species of *Pythium* for comparison with the results obtained by Middleton. The method used was as follows:

Flat-sided glass bottles, with sides measuring about 4 cm by 10 cm, were partly filled with 20 ml cornmeal agar, which was allowed to solidify to a uniform depth with the bottle in a horizontal position. Bottles were inoculated near the mouth with 6 mm discs cut with a cork borer from just behind the advancing margins of potato-dextrose agar cultures. Inoculated bottles were left at room temperature for 16–24 hours, the extent of the growth at the close of that period being indicated by a wax pencil mark on the bottle; subsequent measurements were made from this point. Two bottles of each culture were placed upright in each of the 20 chambers of a multi-temperature incubator which ranged from 6° to 44°C at approximately 2°C intervals. Cultures were incubated for 72 hours, and growth and temperature readings were taken each 24 hours. Variation in temperature within compartments over the 72 hours was usually 1°C or less.

The average daily growth of the fungi at the various temperatures is presented in Table 1. The temperatures given are correct to within 1°C.

IV. DISCUSSION OF SPECIES

There follows a brief description of the species of *Pythium* found in Queensland together with the site from which they were isolated. Morphological and other characters are given only when these differed from those normally associated with the species or were found useful in identification. Acknowledgement of records made by other workers is made in the annotated Host Index.

Table 2

MEASUREMENTS OF OOGONIA AND OOSPORES OF SPECIES OF PYTHIUM FOUND IN QUEENSLAND

Organism	Diameter of Oogonia (μ)		Diameter of Oospores (μ)	
	Range*	Average	Range*	Average
P. acanthicum	14–30	24	..	..
P. aphanidermatum ..	19–27	23	13–27	21
P. debaryanum	13–30	25	17–25	22
P. dissotocum	18–30	24	15–23	19
P. helicoides	22–34	29	24–32	28
P. irregulare	14–22	20	13–20	17
P. myriotylum	20–40	30	16–32	23
P. oligandrum	18–30	24	15–25	21
P. periilum	17–28	21	..	..
P. spinosum	12–22	16	..	..
P. torulosum	14–26	20	..	..
P. ultimum	17–27	21	15–24	19
P. vexans	14–24	18	12–19	16

* 50 measured.

Pythium acanthicum Drechsl.

The fungus had a distinctive cumulous-rosette growth habit (Figure 1a). Only meagre aerial growth was made. Oogonia formed readily on agar media, but sporangia were observed only on watermelon fruit. Wager (1941) also reported difficulty in obtaining the asexual stage.

This fungus was identified mainly on the basis of its distinctive growth habit, growth-temperature relations and spinal characters. Middleton (1943) stated that the short, conical, obtusely-tipped oogonial protuberances of *Pythium acanthicum* are peculiar to the species.

Occurrence in Queensland:

Brassica oleracea L.—Pre-emergence damping-off.

Citrullus vulgaris Schrad.—Blossom-end rot.

Pythium aphanidermatum (Eds.) Fitzp.

The mycelium was abundant, tough and arachnoid (Figure 1b). Inflated filamentous sporangia were produced when mycelium or infected papaw seedlings were transferred to sterile water. In the latter case, zoospores were produced. Sexual fruiting bodies were formed readily on agar media.

A high maximum temperature for growth and the presence of large, barrel-shaped, sessile antheridia typify the species.

Occurrence in Queensland:

Brassica oleracea L.—Rotting roots.

Carica papaya Gaertn.—Damping-off, root rot.

Chloris gayana Kunth—Damping-off.

Cucumis melo L.—Damping-off.

C. sativus L.—Fruit rot.

Dichanthium sericeum (R.Br.) A. Camus—Damping-off.

Hordeum vulgare L.—Stem rot.

Lycopersicon esculentum Mill.—Damping-off, stem rot of transplants.

Medicago sativa L.—Rotting roots.

Nicotiana tabacum L.—Stem rot.

Panicum maximum var. *trichoglume* (K. Schum.) Eyles—Damping-off.

Phaseolus vulgaris L.—Pod rot, stem rot.

Solanum tuberosum L.—Base rot.

Zea mays L.—Stem rot.

Pythium debaryanum Hesse

The growth habit was arachnoid, and the mycelium moderately abundant. Usually spheroidal sporangia and oogonia with monoclinous or diclinous antheridia formed readily on agar media.

Occurrence in Queensland:

Ananas comosus (L.) Merr.—Root rot.

Brassica oleracea.—Damping-off.

Carica papaya—Root and base rot.

Daucus carotae L.—Root rot.

Lupinus angustifolius L.—Root rot.

Lycopersicon esculentum—Damping-off, root rot.

Matthiola incana (L.) R.Br.—Damping-off.

Medicago sativa—Damping-off, root rot.

Passiflora edulis Sims—Root rot.

Persea gratissima Gaertn.—Root rot.

Phaseolus vulgaris—Base rot.

Pinus elliotti Engelm.—Rotting roots on seedlings.

Sesamum indicum L.—Damping-off.

Trifolium incarnatum L.—Damping-off.

Pythium dissotocum Drechsl.

An abundant, arachnoid mycelium was produced. Oogonia were produced readily on agar media, and when mycelium was transferred to sterile water or

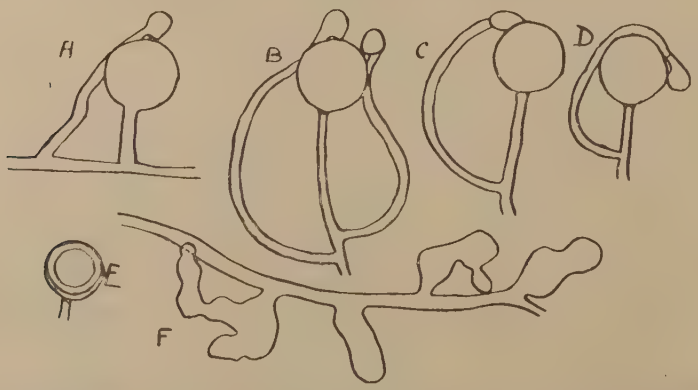

Fig. 2.—Morphological characters of *Pythium dissotocum*. A-D, oogonia and antheridia; E, oogonium with nearly plerotic oospore; F, slightly inflated hyphal elements resembling a sporangium

Petri solution. By analogy with other species of *Pythium* it was assumed that slightly inflated filamentous bodies present in liquid culture were sporangia, but zoospores were not produced.

Oospores were typically plerotic. Antheridia were 1-3 per oogonium, usually monoclinous but occasionally diclinous (Figure 2).

Occurrence in Queensland:

Lupinus digitatus Forsk.—Rotting roots.

Medicago sativa—Damped-off seedlings.

Pythium helicoides Drechsl.

A moderately abundant arachnoid mycelium is formed. No fruiting bodies were formed on potato-dextrose and water agars, but sexual organs were produced on cornmeal agar. Sporangia developed in limited numbers when cornmeal agar blocks containing young mycelium were placed in sterile water for several days. Sporangial proliferation was not observed by the writer, but was reported by Waterhouse (1956).

The large, elongate, cylindrical, intimately-applied antheridial cells with the antheridial stalks often helicoid around the oogonial stalk are characteristic features. A high temperature maximum for growth also typifies this species.

Occurrence in Queensland:

Gossypium sp.—Damped-off seedlings.

Medicago sativa—Damped-off seedlings.

Pinus elliottii—Damped-off seedlings.

Pythium irregulare Buisman

This species produces a moderately-abundant, arachnoid mycelium. Fruiting bodies were formed readily on agar media. The spines of this species are usually few in number, and of irregular size, shape and distribution on the oogonial wall.

Occurrence in Queensland:

Carica papaya—Rotting roots.

Lactuca sativa L.—Rotting roots.

Medicago denticulata Willd.—Damped-off seedlings.

M. sativa—Damped-off seedlings.

M. tribuloides Desr.—Damped-off seedlings.

Trifolium incarnatum—Damped-off seedlings.

Pythium myriotylum Drechsl.

An abundant arachnoid mycelium was produced. Sexual reproductive organs tended to form in clusters on water agar and, more readily, on cornmeal agar. Many oogonia did not contain oospores. Mature oogonia were yellowish-brown in colour. Inflated filamentous sporangia were produced by cultures grown on water agar to which tomato leaf tissue had been added, and also by inoculated lucerne seedlings placed in sterile water.

Besides the high maximum temperature for growth, the species is typified by the crook-necked antheridial cells which make basal and apical contact with the oogonium.

Occurrence in Queensland:

Lupinus digitatus—Damping-off.

Lycopersicon esculentum—Tap-root rot.

Medicago sativa—Damping-off, root rot.

Nicotiana tabacum L.—Damping-off.

Pisum sativum L.—Damping-off.

Pythium oligandrum Drechsl.

This species produced a meagre aerial growth of mycelium which, after a few days, took on a dense woolly appearance. Sexual reproductive structures were produced readily on agar media, but sporangia were not seen.

The species is characterised by conical, acutely-tipped oogonial protuberances and a pulvinate growth habit.

Occurrence in Queensland:

Carica papaya—Rotting roots.

Gerbera jamesonii Bolus—Rotting roots.

Persea gratissima—Rotting roots.

Pythium periilum Drechsl.

A Pythium regarded by Middleton (1959) as probably belonging to this species had a pulvinate growth habit. Oogonia and diclinous antheridia were produced on cornmeal agar, but the proportion of oogonia with oospores was always small. Inflated filamentous sporangia were produced on irrigation of cultures growing on water agar in which lucerne tissue had been incorporated.

Occurrence in Queensland:

Medicago sativa—Rotting roots.

Saccharum officinarum L.—Roots (Isolated by Queensland Bureau of Sugar Experiment Stations and identified by Rands (1939)).

Pythium spinosum Saw.

This had an abundant, arachnoid mycelium. Reproductive structures formed readily on agar media, and when mycelium was placed in sterile water.

Long, digitate, obtusely-tipped oogonial protuberances typify the species.

Occurrence in Queensland:

Ananas comosus—Rotting roots.

Brassica oleracea—Damping-off.

Camellia japonica L.—Rotting roots.

Carica papaya—Rotting roots.

Cucurbita maxima L.—Damping-off.

Passiflora edulis—Rotting roots.

Persea gratissima—Rotting roots.

Phaseolus vulgaris—Seed rot and damping-off.

Pinus elliottii—Rotting roots on seedlings.

Pythium splendens Braun.

The mycelium was arachnoid and moderately abundant. Sporangia were produced readily on cornmeal agar, water agar and potato-dextrose agar, but oogonia failed to form in four weeks on these media. Middleton (1943) and Wager (1941) also reported difficulty in obtaining the sexual stage.

The species was identified on the basis of its sporangial, growth-temperature and cultural characteristics. According to Middleton (1943) the large, spherical, densely-granular, terminal sporangia are unique.

Occurrence in Queensland:

Annona squamosa L.—Root rot.

Pinus elliottii—Root rot.

Pisum sativum—Damping-off.

P. splendens was isolated on several occasions from soil, using the apple technique devised by Campbell (1949).

Pythium torulosum Coker and Patterson

This fungus has a fairly dense appressed, broadly-rosette growth habit (Figure 1c), and was the slowest growing species studied. Inflated filamentous sporangia were formed following the irrigation of cultures growing on water agar in which lucerne tissue had been incorporated. Oogonia were produced scantily on agar media; they measured somewhat larger (14–26μ) than the 12-19μ quoted by Middleton (1943). The monoclinous antheridia, one or two per oogonium and arising fairly close to the oogonium, were typical of the species (Figure 3). The maximum temperature was somewhat higher (39°C) than the 34-37°C given by Middleton (1943).

Occurrence in Queensland:

Medicago sativa—Rotting roots.

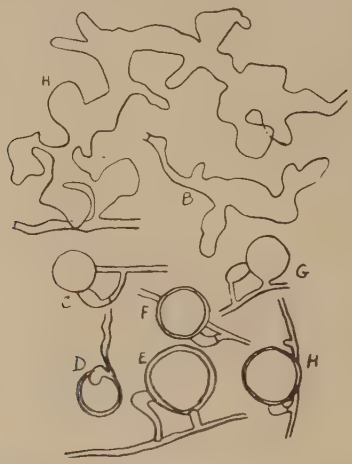

Fig. 3.—Morphological characters of *Pythium torulosum*. A, B, sporangia; C-H, oogonia and antheridia.

Pythium ultimum Trow.

This species had an abundant, arachnoid mycelium. Reproductive organs were usually produced readily on agar media. A single, swollen, sausage-shaped antheridium arising very close to the oogonium typifies the species.

Occurrence in Queensland:

Alyssum maritimum L.—Damping-off.

Antirrhinum majus L.—Base rot.

Aster sp.—Damping-off.

Brassica oleracea—Damping-off.

Carica papaya—Damping-off; root and base rot.

Linum usitatissimum L.—Damping-off.

Lupinus angustifolius L.—Root and base rot.

Lycopersicon esculentum—Damping-off, base rot.

Medicago sativa—Root rot.

Persea gratissima—Rotting roots.

Phaseolus vulgaris—Stem rot, tip blight.

Pinus elliottii—Damping-off.

P. patula Schlecht & Cham.—Seedling root rot.

Pisum sativum—Damping-off.

Solanum tuberosum—Base rot.

Vigna sinensis (L.) Endl. ex Hassk.—Damping-off.

Pythium vexans de Bary.

This species had a characteristic rosette growth habit and a "combed silk" margin (Figure 1d). Sporangia were usually produced readily on agar media; small oogonia with cylindrical, broadly-attached antheridia sometimes formed sparsely on water agar after long incubation, but were more readily produced on cornmeal agar (Figure 4). Some isolates which agreed with *P. vexans* in cultural and sporangial characters failed to produce oogonia on any agar media used.

Occurrence in Queensland:

Annona squamosa—Rotting roots.

Brassica oleracea—Rotting roots.

Carica papaya—Rotting roots and bases.

Medicago sativa—Damping-off.

Persea gratissima—Rotting roots.

It was also frequently isolated from soil by Campbell's (1949) technique.

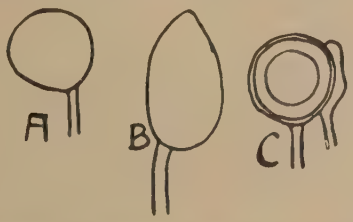

Fig. 4.—Morphological characters of *Pythium vexans*. A, B, terminal sporangia; C, oogonium and antheridium.

V. PRESENTATION OF DATA IN THE HOST INDEX

The host list which follows is presented with the botanical families in alphabetical order.

Where the host record is not listed by Middleton (1943) the species name of the *Pythium* concerned is preceded by an asterisk.

Where it is considered that the fungus was a primary pathogen, this is indicated by a +. Where pathogenicity is doubtful the + sign is omitted. Where inoculation experiments have confirmed the pathogenicity the symbol ++ is used.

Unpublished records contributed by other workers are acknowledged by inserting the contributor's name after the record. Records appearing in published articles are referred to the References in the usual way.

ANNOTATED HOST INDEX

Annonaceae

Annona muricata L. (sour sop)
- **Pythium* sp. — damping-off++ (G. S. Purss).

Annona squamosa L. (custard apple)
- **P. splendens* — damping-off+.
- **P. vexans* — root rot.

Bromeliaceae

Ananas comosus (L.) Merr. (pineapple)
- *P. debaryanum* — root rot.
- **P. spinosum* — root rot.

Cactaceae

Opuntia inermis DC. (prickly pear)
- **Pythium* sp. — root rot+ (Tryon 1912).

Caricaceae

Carica papaya Gaertn. (papaw)
- *P. aphanidermatum* — damping-off, root rot+ (Teakle 1957).
- *P. debaryanum* — root-rot+ (Teakle 1957) and base rot++ (J. H. Simmonds).
- *P. irregulare* — root rot (Teakle 1957).
- **P. oligandrum* — root rot (Teakle 1957).
- *P. spinosum* — root rot (Teakle 1957).
- *P. ultimum* — damping-off+; root and base rot++ (Ashby 1935; Simmonds 1937).
- *P. vexans* — root and base rot (Teakle 1957).
- *Pythium* sp. — ground rot of fruit+ (G. D. Bowen).

Chenopodiaceae

Beta vulgaris L. (beetroot, silverbeet)
- *Pythium* sp. — damping-off+.

Compositae

Aster sp. (aster)
- **P. ultimum* — damping-off+.

Gerbera jamesonii Bolus. (gerbera)
- **P. oligandrum* — root rot (B. L. Winks).

Lactuca sativa L. (lettuce)
- **P. irregulare* — root rot.

Cruciferae

Alyssum maritimum L. (alyssum)
- **P. ultimum* — damping-off+.

Brassica oleracea L. (cabbage, cauliflower, broccoli)

**P. acanthicum*	damping-off.
P. aphanidermatum	root rot.
P. debaryanum	damping-off+.
P. spinosum	damping-off.
P. ultimum	damping-off++.
**P. vexans*	root rot.

Matthiola incana L. (stock)

**P. debaryanum*	damping-off+.

Cucurbitaceae

Citrullus vulgaris Schrad. (watermelon)

P. acanthicum	fruit rot.

Cucumis melo L. (rockmelon)

P. aphanidermatum	damping-off+.
P. spinosum	damping-off+ (B. L. Winks).

Cucumis sativus L. (cucumber)

P. aphanidermatum	fruit rot++ (J. C. Johnson).
Pythium sp.	fruit rot+.

Cucurbita maxima L. (pumpkin)

**P. spinosum*	damping-off+.

Gramineae

Chloris gayana Kunth. (Rhodes grass)

**P. aphanidermatum*	damping-off+ (J. K. Leslie).

Dichanthium sericeum (R.Br.) A. Camus (Queensland blue grass)

**P. aphanidermatum*	damping-off++ (J. K. Leslie).

Hordeum vulgare L. (barley)

**P. aphanidermatum*	stem rot+ (B. L. Winks).

Panicum maximum var. *trichoglume* (K. Schum.) Eyles (green panic)

**P. aphanidermatum*	damping-off+ (J. K. Leslie).

Saccharum officinarum L. (sugar-cane)

P. periilum	root rot++ (Bureau of Sugar Experiment Stations).

Zea mays L. (maize)

P. aphanidermatum	stem rot+ (B. L. Winks).

Lauraceae

Persea gratissima Gaertn. (avocado)

**P. debaryanum*	root rot.
**P. oligandrum*	root rot.
**P. spinosum*	root rot.
**P. ultimum*	root rot.
P. vexans	root rot.

Leguminosae

Lupinus angustifolius L. (New Zealand blue lupin)	
P. debaryanum	root rot+.
**P. ultimum*	root and base rot+.
L. digitatus Forsk. (West Australian blue lupin)	
P. dissotocum	root rot+.
**P. myriotylum*	damping-off+.
Medicago denticulata Willd. (burr medic)	
**P. irregulare*	damping-off+.
M. sativa L. (lucerne)	
**P. aphanidermatum*	rotting roots.
**P. debaryanum*	damping-off and root rot+.
P dissotocum	damping-off++.
**P. helicoides*	damping-off+.
**P. irregulare*	damping-off+.
**P. myriotylum*	root rot++ (Teakle 1956).
**P. periilum*	root rot.
**P. torulosum*	root rot.
P. ultimum	root rot.
P. vexans	damping-off.
M. tribuloides Desr. (barrel medic)	
**P. irregulare*	damping-off+.
Melilotus indica All. (hexham-scent)	
Pythium sp.	root rot.
Phaseolus vulgaris L. (french bean)	
P. aphanidermatum	pod rot++ (J. C. Johnson) and stem rot+ (Simmonds 1950).
P. debaryanum	base rot+.
**P. spinosum*	seed rot, damping-off+.
P. ultimum	tip blight, stem, base and root rot+.
Pisum sativum L. (pea)	
**P. myriotylum*	damping-off+.
**P. splendens*	damping-off+.
P. ultimum	damping-off++.
Trifolium incarnatum L. (crimson clover)	
**P. debaryanum*	damping-off+.
**P. irregulare*	damping-off+.
Vigna sinensis (L.) Endl. ex. Hassk. (cowpea)	
**P. ultimum*	damping-off+.

Linaceae

Linum usitatissimum L. (linseed)	
P. ultimum	damping-off+.

Malvaceae
Gossypium hirsutum L. (cotton)
**P. helicoides* damping-off+.

Musaceae
Musa sp. (banana)
Pythium sp. root rot.

Myrtaceae
Eucalyptus pilularis Sm. (blackbutt)
**Pythium* sp. damping-off (Simmonds 1951).

Passifloraceae
Passiflora edulis Sims (passion fruit).
**P. debaryanum* root rot.
**P. spinosum* root rot.

Pedaliaceae
Sesamum indicum L. (sesame)
**P. debaryanum* damping-off+.

Pinaceae
Pinus elliottii Engelm. (slash pine)
**P. spinosum* rotting roots on seedlings
**P. splendens* rotting roots on seedlings
**P. ultimum* damping-off++. (B. L. Winks.)
P. radiata D. Don. (radiata pine)
P. ultimum damping-off++. (B. L. Winks.)

Rubiaceae
Pentas sp.
Pythium sp. stem rot.

Rutaceae
Citrus sp.
Pythium sp. damping-off+.

Scrophulariaceae
Antirrhinum majus L. (snapdragon)
P. ultimum base rot+.

Solanaceae
Capsicum frutescens L. (chili)
Pythium sp. stem rot.
Lycopersicon esculentum Mill. (tomato)
P. aphanidermatum damping-off, stem rot of transplants+; fruit rot+. (B. L. Winks.)
P. debaryanum damping-off, root and base rot+.
P. myriotylum stem rot of transplants+.
P. ultimum damping-off, root and base rot+.

Nicotiana tabacum L. (tobacco)

P. aphanidermatum	stem rot (W. Pont).
P. myriotylum	damping-off+.

Petunia hybrida Vilm.

Pythium sp.	stem rot+.

Solanum tuberosum L. (potato)

P. aphanidermatum	base rot+.
P. ultimum	base rot, soft rot of tuber+.

Theaceae

Camellia japonica L. (camellia)

**P. spinosum*	root rot.

Umbelliferae

Daucus carota L. var. *sativa* DC. (carrot)

P. debaryanum	root rot.

Zingiberaceae

Zingiber officinale Rosc. (ginger)

P. spinosum	rhizome rot (secondary to *Fusarium oxysporum*).

VI. ACKNOWLEDGEMENTS

The author is indebted to officers of the Queensland Department of Agriculture and Stock who contributed specimens and cultures. Dr. G. M. Waterhouse kindly checked the identity of cultures of *Pythium acanthicum, P. helicoides, P. irregulare, P. myriotylum, P. oligandrum,* and *P. spinosum*. Dr. J. T. Middleton identified *P. dissotocum* and *P. periilum,* and checked the identity of *P. torulosum.* Mr. J. H. Simmonds (Government Plant Pathologist) gave helpful advice during the preparation of the manuscript.

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(Received for publication September 1, 1959)

CONTROL OF LIGHT-BROWN APPLE MOTH

By M. BENGSTON, B.Sc.*

SUMMARY

Alternatives to lead arsenate for the control of light-brown apple moth, *Austrotortrix postvittana* (Walk.), were tested in three spray trials in apple orchards in the Stanthorpe district during the 1954-55 season.

Programmes incorporating DDD were generally superior to all others, and at the same time avoided the foliage damage and spray residue problems associated with the use of lead arsenate. Two sprays of DDD 0.1 per cent., one applied in late November and the other in late January, are basic for the control of light-brown apple moth.

I. INTRODUCTION

Light-brown apple moth, *Austrotortrix postvittana* (Walk.), a native insect, was not an important pest in Queensland until the 1947-48 season (May 1948). Since then it has been an important pest of apples and pears, a serious pest of grapes and a minor one of stone fruits. This increase in pest status coincided with the general change to DDT in spray programmes.

May (1952) recommended the inclusion in the DDT programme for apples and pears of two sprays of lead arsenate 3 lb per 100 gal, the first in late November and the other in late January. On early-maturing varieties the second lead arsenate spray was replaced by a nicotine sulphate/white oil mixture.

The three trials set out during the 1954-55 season in the Stanthorpe district, and which are currently described, were prompted by the disadvantages associated with the use of lead arsenate and the advent of new materials.

II. MATERIALS

The materials and active concentrations used were:—

DDT.—An emulsion concentrate containing 25 per cent. w v *p.p'* isomer: used at 0·1 per cent.

Dieldrin.—An emulsifiable preparation containing 16 per cent. w/v active ingredient: 0·05 per cent.

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Endrin.—An emulsifiable preparation containing 20 per cent. w/v active ingredient: 0·025 and 0·05 per cent.

Lead arsenate.—A powder containing 31 per cent. As_2O_5 as lead arsenate, and 1 per cent. dispersing agent; containing less than 0·5 per cent. water-soluble arsenic compounds: 3 lb per 100 gal.

Nicotine.—A concentrate containing 40 per cent. nicotine as nicotine sulphate: 1¼ pt per 100 gal.

Parathion.—An emulsifiable preparation containing 50 per cent. w/v active ingredient: 0·01 per cent.

DDD (TDE).—An emulsion concentrate containing 30 per cent. w/v *p.p'* isomer: 0·1 per cent.

Thiram.—A dispersible powder containing 80 per cent. w/w active ingredient: 1½ lb per 100 gal.

Urea.—A material containing 46 per cent. nitrogen as urea: 5 lb per 100 gal.

White oil.—An oil containing 80 per cent. w/w mineral oil: 2½ pt per 100 gal.

III. METHODS

An 8 x 4 randomized layout was used with single-tree plots in Trial 1 (variety Delicious), 2-tree plots in Trial 2 (Jonathan), and two separate blocks with single-tree plots in Trial 3 (Granny Smith).

Prior to treatments the trials received uniform applications of sprays. These included:—Trial 1, superior oil 3 in 100 while dormant; Trial 2, superior oil 3 in 100 while dormant, lime sulphur 1 in 30 at "pink" and lead arsenate 3 lb, hydrated lime 3 lb, casein spreader 1 lb, colloidal sulphur 2 lb, lime sulphur ½ gal in 100 gal of water at "calyx"; Trial 3, superior oil 3 in 100 while dormant.

Selection of materials and trial programmes was influenced by the necessity to control other members of the apple pest complex (see May 1952). These programmes are given in Table 1. Treatments were applied at a pressure of 200-250 lb per sq. in. using a small power spray with a hand-operated lance. Complete tree cover was aimed at. Application dates of cover sprays were as follows:

Trial 1: November 8, November 26-27, December 12, January 15 and February 3;

Table 1

TRIAL PROGRAMMES

Programme	Cover Sprays					
	1	2	3	4	5	
	All trials	All trials	All trials	All trials	Trials 1 and 3	Trial 2
A	DDT	DDT plus lead arsenate plus parathion	Parathion	DDT	DDT plus lead arsenate plus white oil	DDT plus white oil plus nicotine
B	DDT	DDT plus DDD plus parathion	Pharathion	DDT	DDT plus DDD	DDT plus DDD
C	Endrin 0·025%	Endrin 0·025% plus lead arsenate plus parathion	Parathion	Endrin 0·025%	Endrin 0·025% plus lead arsenate	Endrin 0·025% plus white oil plus nicotine
D	Endrin 0·025%	Endrin 0·025% plus DDD plus parathion	Parathion	Endrin 0·025%	Endrin 0·025% plus DDD	Endrin 0·025% plus DDD
E	Endrin 0·05%	Endrin 0·05% plus parathion	Parathion	Endrin 0·05%	Endrin 0·05%	Endrin 0·05%
F	Dieldrin	Dieldrin plus parathion	Parathion	Dieldrin	Dieldrin	Dieldrin
Ga Trial 1 and Trial 3 (block 1)	Programme A plus urea	Programme A plus urea	Parathion	Programme A plus urea	Programme A plus urea	..
Gb Trial 2 and Trial 3 (block 2)	Programme A plus thiram	Programme A plus thiram	Parathion	Programme A plus thiram	Programme A plus thiram	..
H	Untreated	Untreated	Untreated	Untreated	Untreated	Untreated

Table 2

PERCENTAGE OF DAMAGED FRUIT

Programme (important materials indicated)	Trial 1 (Delicious)		Trial 2 (Jonathan)		Trial 3 (Granny Smith) Block 1		Trial 3 (Granny Smith) Block 2	
	Transformed Mean*	Equivalent Mean	Transformed Mean*	Equivalent Mean	Transformed Mean*	Equivalent Mean	Transformed Mean*	Equivalent Mean
A. DDT plus lead arsenate ..	13·3	5·3	20·0	11·7	21·7	13·7	16·8	8·3
B. DDT plus DDD	11·7	4·1	12·6	4·7	10·8	3·5	9·0	2·4
C. Endrin 0·025% plus lead arsenate	12·2	4·5	16·3	7·9	18·7	10·3	14·0	5·9
D. Endrin 0·025% plus DDD ..	9·9	2·9	12·0	4·3	11·1	3·7	9·6	2·8
E. Endrin 0·05%	14·4	6·2	15·5	7·1	20·7	12·5	19·1	10·7
F. Dieldrin 0·05%	19·2	10·9	28·6	23·0	25·5	18·5	27·1	20·8
Ga. Programme A plus urea ..	14·5	6·3	..	..	..	..	18·6	10·1
Gb. Programme A plus thiram ..			22·4	14·5	19·3	10·9		..
H. No treatment	18·2	9·7	37·6	37·2	25·0	17·9	24·3	17·0
Necessary differences for 5% significance	3·0		5·7		4·1		4·1	
Necessary differences for 1% significance	4·1		7·8		5·6		5·5	

* Inverse sine.

Trial 2: November 2, November 23, December 6, January 1 and February 1;

Trial 3: November 6, November 24, December 5-6, January 1 and February 2.

As heavy codling moth, *Cydia pomonella* (L.), stinging was occurring, and at the request of the orchardist, an additional DDT treatment was applied on January 20 to trees concerned with Programmes 3, 4 and 6 in Trial 1.

All fruit, including windfalls, were examined for larval damage, and recorded simply as either damaged or sound.

IV. RESULTS

Results and further details are given in Table 2.

Programmes B and D (Table 1) incorporating DDD gave satisfactory results and were generally superior to all others; these also avoided a residue problem (see Bengtson and Winks 1957), and foliage damage, caused by arsenic, which may result in premature leaf-fall. Programmes A, C and G, incorporating lead arsenate, and E, using endrin 0·05 per cent., were moderately effective. Programme F, based on dieldrin, was of little value. The addition of either urea or thiram (Ga and Gb) to the standard (A) did not lower efficacy.

On the results of these trials May and Bengtson (1955) in a spray programme against pests of apples and pears included two sprays of DDD 0·1 per cent., one in late November and the other in late January, for the control of light-brown apple moth. Experience in commercial orchards has confirmed the efficacy of this programme when spraying is thorough.

V. ACKNOWLEDGEMENTS

Orchardists in the Stanthorpe district provided the necessary facilities for conducting these trials. All statistical analyses were carried out by Mr. P. B. McGovern, Senior Biometrician. This assistance is gratefully acknowledged.

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(Received for publication September 9, 1959)

USE OF SYNTHETIC OESTROGENS FOR PROMOTING WEIGHT GAINS IN BEEF STEERS GRAZING ON NATIVE PASTURES

By M. A. BURNS, Q.D.A.H.*, and D. N. SUTHERLAND, B.V.Sc.†

SUMMARY

In two trials on unimproved pasture at the Beef Cattle Pasture Research Station, "Brian Pastures," Gayndah, beef steers implanted at levels of 30 mg and 60 mg with the synthetic hormone hexoestrol made significantly greater liveweight gains than comparable untreated cattle. Treated animals had a slightly better depth of eye muscle and carried less fat cover than the controls. In one trial, carcasses of the control animals graded higher than those of the treated animals, but in the other trial the carcasses of both treated and untreated cattle graded equally well. Certain adverse effects were noted in steers treated at both levels.

I. INTRODUCTION

In recent years there have been numerous reports of an increase in growth rate of cattle following treatment with oestrogenic hormones, either by oral administration or by subcutaneous implantation (Burroughs *et al.* 1954; O'Mary *et al.* 1953; O'Mary and Cullison 1956). Most reports of increased growth rate refer to cattle in feed lots, but more recent information from overseas countries indicates that significant responses to treatment have been obtained by implantation of cattle grazing on high quality pasture and crop (O'Mary and Cullison 1956; Kercher 1958).

The observations in this study were made on cattle implanted with hexoestrol at two levels and dependent solely on unimproved pasture for grazing.

II. MATERIALS AND METHODS

Two trials were carried out at the Beef Cattle Pasture Research Station, "Brian Pastures", Gayndah. This property receives an average annual rainfall of about 29 in. and has a pasture consisting mainly of black spear grass (*Heteropogon contortus*) and a number of blue grasses (species of *Bothriochloa* and *Dichanthium*). These are essentially summer-growing species and are virtually non-productive during the winter months.

The first trial was commenced in November 1957, and drought conditions prevailed for the first 56 days of the trial. Three groups of cattle each comprising 16 3-year-old Hereford steers, four 4-year-old Hereford steers and three 3-year-old Hereford–Aberdeen Angus steers were used in a randomized block design. The

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three treatments involved were an implant of 30 mg hexoestrol, one of 60 mg hexoestrol, and no implant. Initial weights were taken and the stock were weighed regularly at 28-day intervals. At the termination of the trial on April 26, 1958, the stock were slaughtered and carcass grade and measurements of the eye muscle and fat cover were obtained.

The second trial was commenced in December 1958 and terminated in April 1959. Forty-six 3-year-old Hereford steers were split into two groups for paired comparison. One group was retained as the control group and the animals in the other group were given an implant of 30 mg hexoestrol.

In both trials the animals were depastured in the same paddock.

III. RESULTS

The growth rates of the groups in the two trials are shown in Figure 1. The difference in initial weight and overall growth rate between the two trials is due to the drought conditions prevailing prior to and during the early part of the first trial. Table 1 shows the essential growth rate information from both trials. Significant differences were recorded in rate of gain in both trials. In the first trial the two levels of hexoestrol were associated with gains significantly greater than those of the control animals ($P<0{\cdot}05$). In the second trial, the 30 mg implant was again associated with increased gains, the difference again being significant at the 5 per cent. level.

The dressed weight of the carcasses in the first trial reflected the differences shown in the rate of gain, both treated groups again exceeding the control group

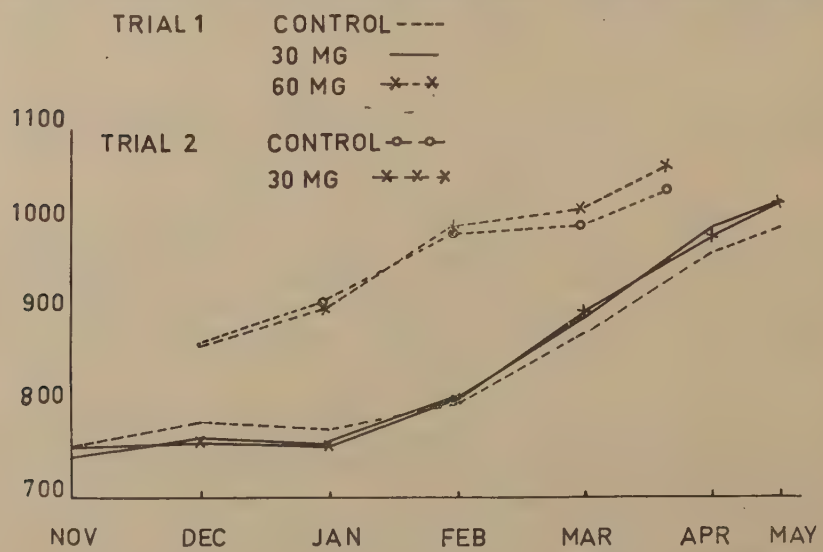

Fig. 1.—Graph of the average weights (in lb) of the steers in the treated groups during the two trials.

Table 1

GROWTH RATE DATA

Group	Average Initial Weight (lb)	Average Daily Gain (lb/day)	Average Final Weight (lb)	Average Dressing Weight (lb)	Eye Muscle Depth (cm)	Fat Cover (cm)
Trial 1						
Control	751	1·6	987	510	4·8	2·2
30 mg implant ..	744	1·8	1,022	523	4·9	1·8
60 mg implant ..	752	1·7	1,021	529	5·1	1·8
Trial 2						
Control	865	1·6	1,038	553	4·8	1·8
30 mg implant ..	861	1·9	1,059	560	5·1	1·7

($P<0·01$). However, there was no significant difference between the average dressed weight of the implanted group and that of the control group in the second trial.

The differences in eye muscle depth and fat thickness over the eye muscle between the treated groups and the control group in both trials were not significant.

In the first trial, the control group averaged a higher grade than the two treated groups, lack of finish being the major factor responsible for the lower grading of the carcasses in the treated groups (Table 2). In the second trial, there was no difference in grade between the carcasses from either the control or the treated group. However, the carcasses in the second trial were not graded on the same basis as those in the first trial.

Table 2

GRADING OF CARCASSES

Group	Grade		
	Chiller	First	Second
Trial 1			
Control	18	4	1
30 mg implant	9	12	2
60 mg implant	10	10	3
Trial 2*			
Control	..	23	0
30 mg implant	..	23	0

* In the second trial, the chiller grade was not operating and first grade was the highest grade.

IV. DISCUSSION

Under the conditions which existed during the 1957–58 trial, steers treated at both levels showed an increased growth rate over the control steers but the quality of their carcasses was inferior to that of the untreated steers. However,

the plane of nutrition on which the animals were maintained during the first two months of the trial was low, so reasonable gains were not obtained.

In the 1958–59 trial, steers treated at the 30 mg level also showed an increased growth rate over the untreated steers. However, at slaughter, the carcasses of both groups graded equally well.

The plane of nutrition throughout the trial was high. The cattle were in good forward condition at the time of implantation and at slaughter both treated and untreated animals had reached a desirable degree of finish.

Body changes and changes in behaviour were noted in steers in the treated groups in both trials. The body changes took the form of elevation of the tail head, with accompanying tail depressions, sideways sloping of the rump, swayback, some coarseness over the shoulders and teat development.

The costs of the synthetic hormone used represented 1s. per head for animals treated with 60 mg and 6d. per head for animals treated with 30 mg.

In both trials the differences in value between carcasses of the treated and untreated groups were very small. In the 1957–58 trial the down-grading of carcasses of treated animals offset the increase in carcass weight due to treatment. The group treated with 30 mg netted 4s. 5d. per head less and the group treated with 60 mg 1s. per head less than the controls. These differences were not significant. As differences in carcass weight in the 1958–59 trial were not significant, the differences in net returns per head were also not significant.

V. ACKNOWLEDGEMENTS

The assistance of other officers of the Cattle Husbandry Branch, Department of Agriculture and Stock, in the collection and compilation of the data is acknowledged. The statistical analyses of the data were carried out by Mr. A. W. Beattie and Miss D. E. Nunn. The co-operation of the management and staff of Thomas Borthwick and Sons (Australasia) Ltd. (Moreton Freezing Works) and of officers of the Commonwealth Department of Primary Industry made possible the collection of the carcass information.

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(Received for publication September 5, 1959)

DEER IN QUEENSLAND

By C. ROFF*

SUMMARY

Fallow deer, *Cervus dama* L., axis or chital deer, *C. axis* Erxleben, red deer, *C. elephas* L., and rusa deer, *C. unicolor* Kerr, are present in Queensland, and under fauna conservation legislation are protected.

Results of the first survey since deer were introduced over 80 years ago indicate that present populations and distributions of the fallow, axis and rusa deer do not warrant and would not support a policy of open season hunting. Red deer offer possibilities in this regard, but before implementation could be considered, well defined and adequately staffed management areas would be required.

I. INTRODUCTION

Under Queensland conservation laws, deer are protected and may be destroyed only as pests after special permits have been obtained. In recent years attention has been directed to these introduced animals by requests for open hunting seasons, and in some instances by reports of illegal shooting. Accordingly,

Fig. 1.—Crossing Cooyar Creek while hunting red deer, April 5, 1956.

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to appreciate the present position earlier writings were consulted, and from October 1, 1955, to June 30, 1957, a relevant field survey was made. This included traverses, usually over a long day, more intensive observations during hunting trips (note Figure 1), and discussions with residents and officers of the Department of Forestry and the Department of Agriculture and Stock who are familiar with and interested in deer. Inspections concerned with applications for permits to destroy deer provided further opportunities for field observations.

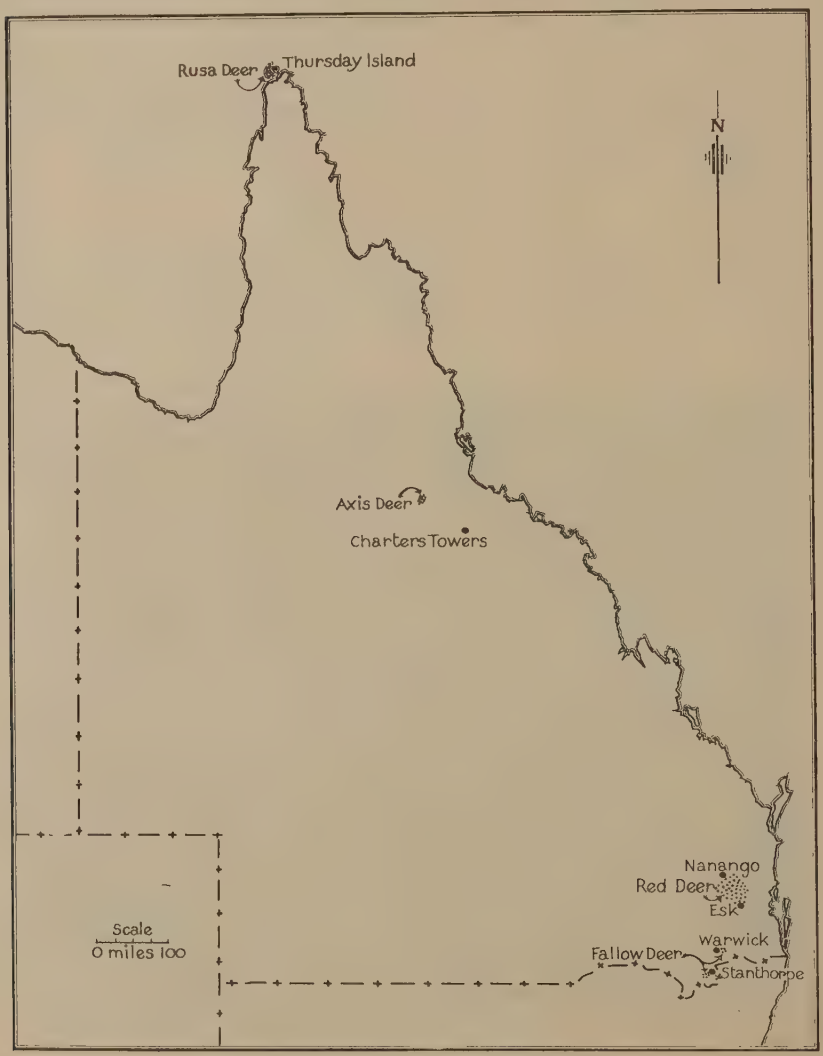

Fig. 2.—Distribution of deer in Queensland.

Fallow deer, *Cervus dama* L., axis or chital deer, *C. axis* Erxleben, red deer, *C. elephas* L., and rusa deer, *C. unicolor* Kerr, have been released in Queensland and still exist (Figure 2). Each is discussed under species heading.

II. FALLOW DEER

(a) Importations and Releases

According to Bentley (1957) fallow deer were introduced into Tasmania from Great Britain about 1850. Three stags and seven hinds were despatched to the Acclimatisation Society of Queensland (referred to hereafter in literature references as A.S.Q.) by Mr. J. Bisdee of Hobart (A.S.Q. 1865), and arrived in Brisbane on the vessel "Cawarra" on February 17, 1865 (A.S.Q. 1866). These were held at Bowen Park, Brisbane, for several years; during 1866, six calves were dropped, of which four survived (A.S.Q. 1866), and by 1869 the deer were breeding well in captivity (A.S.Q. 1869).

Details of all releases are somewhat obscure, but by 1870 several lots from Bowen Park had been liberated on the Darling Downs at Maryvale and Westbrook, and in 1873 these were reported as doing well (A.S.Q. 1873a). Others liberated on the Main Range near Toowoomba had bred successfully (A.S.Q. 1873b). Six released on "Canning Downs", near Warwick, in 1872 (A.S.Q. 1874) were a nuisance to crops and were exterminated (Hall 1923). Deer had been seen near Allora, but these were quickly destroyed and none has been observed in that district during recent years.

About 1890 a number of stags and hinds were brought from Tenterfield, New South Wales, by Mr. C. F. White of "Pikedale", near Stanthorpe, and released on that property.

(b) Dispersal and Comments

This species is confined to areas associated with only two release points (Figure 3). In the Upper Freestone Valley, mountainous country affords some protection: in the lower lands, damage to field crops may be experienced but the goodwill of those most concerned is basic to the continued existence of fallow deer in the area. Wider dispersal onto the Darling Downs and adjacent country has been prevented by urban populations and the development of closely settled agricultural lands.

On "Pikedale" the deer (Figures 4 and 5) may sometimes forage in lucerne and improved pastures, but this herd of about 60 is primarily a private one. The small number present in country closely adjacent to this property was not determined.

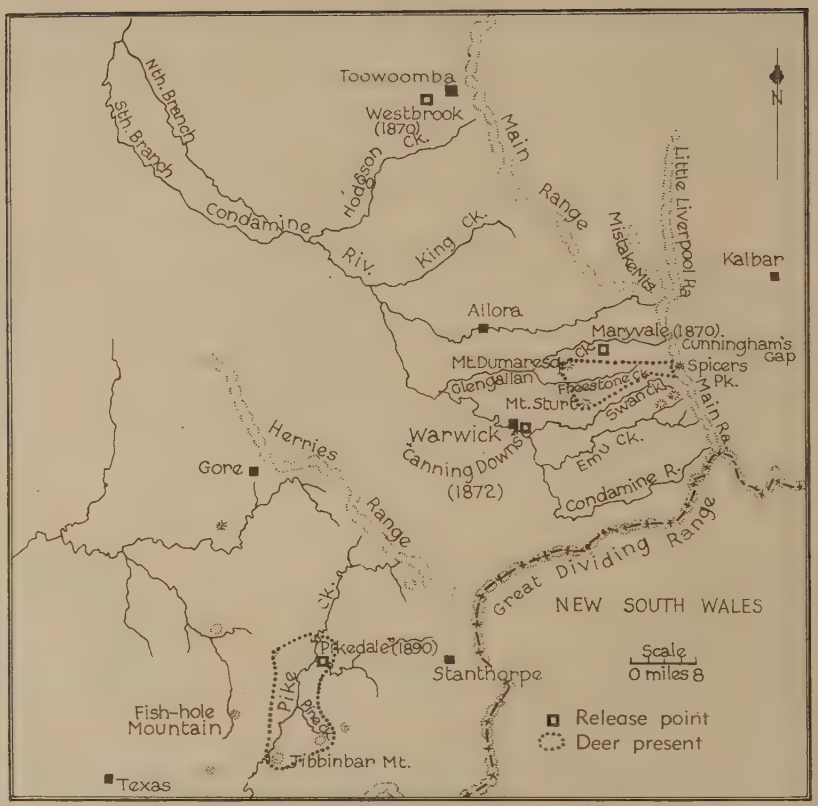

Fig. 3.—Dispersal of fallow deer.

Fig. 4.—A young fallow stag, Pike Creek, April 8, 1957.

Fig. 5.—Antlers from a fallow deer, "Pikedale", July 8, 1957.

III. AXIS DEER

(a) Importations and Releases

In 1867 Javan spotted deer were imported from Batavia by the Acclimatisation Society of Queensland (A.S.Q. 1868), and during 1872 five of these, which were then referred to as axis deer, were released on Mr. A. Weinholt's

property, "Maryvale", on the Darling Downs in south-eastern Queensland (A.S.Q. 1872). Various reports (A.S.Q. 1873a, b and d) indicate that progeny of these deer were observed.

During one of the voyages of the steamship "Quetta", the master (Captain Jarvis E. Withers) was given an axis deer in Ceylon. On arrival at Townsville in August, 1886, this hind was given to Mr. William Hann, a passenger (Anon. 1886) and the owner of "Maryvale", via Charters Towers, North Queensland. A few years later Mr. Hann imported a stag and a hind (Figure 6), and later another stag. These and progeny were eventually released.

Fig. 6.—Mr. William Hann, of "Maryvale", via Charters Towers, with axis stag and hind imported from Ceylon. (Copy of a photograph taken in 1889.)

(b) Dispersal and Comments

The presence of axis deer on the Darling Downs has not been recorded during recent years.

Some 300 are on "Maryvale", Charters Towers (Figure 8), and a herd of similar size is present on "Niall", which is also on Maryvale Creek (Figure 7). Dingoes prey heavily on the deer, which seldom move more than a few miles from the homesteads.

Fig. 7.—Dispersal of axis deer.

During January, 1956, two were seen on "Wando Vale", 30 miles west of "Maryvale", Charters Towers, and in that year another two were observed on "Wairuna", 80 miles north. On May 8, 1956, an axis stag was shot on "Russleigh", via Isisford, a locality about 360 miles south-west of "Maryvale". No reasonable explanation is offered for this dispersal.

Fig 8.—Semi-domesticated young axis hind, "Maryvale", via Charters Towers. (Photograph by E. C. Clarke, "Maryvale", 1956.)

IV. RED DEER

(a) Importations and Releases

There are several references to the introduction of red deer into Queensland for the purposes of providing additional food and sport for the early colonists (Anon. 1873; A.S.Q. 1873b; Pugh 1874; Banks 1931). The first consignment, two stags and four hinds from the Windsor Park herd in England, was a gift from Queen Victoria to the Acclimatisation Society of Queensland, and arrived in Brisbane on the "Great Queenslander" in early September of 1873. On September 23 of that year these animals were released near Scrub Creek, "Cressbrook" (A.S.Q. 1873c) (Figure 9). A second consignment of six deer from the Duke of Richmond's estate in England was imported by the Acclimatisation Society, and on June 2, 1874, was released at the same locality, when it was apparent that the original releases were thriving in the nearby ranges (A.S.Q. 1874).

Table 1

FIELD SURVEY OF RED DEER

Date	Number Sighted	Locality	Observer
1955			
Oct. 1	1	East Branch, Brisbane River	C
11	1	East Branch, Brisbane River	C
10	5	Oaky Creek (Greenwood Creek)	A & B
10	15	Oaky Creek	B
10	5	Marble Top Mountain	A & B
..	1	Wengenville	H
Nov. 11	1	Tom Tom Scrub, near Oaky Creek	A & B
..	4	S.F.R. 299, Nanango	B
..	1	S.F.R. 299, Nanango	B
Dec. ..	1	Nukinenda Creek	D
..	1	Nukinenda Creek	D
1956			
Feb. ..	1	S.F.R. 299, Nanango	B
..	1	S.F.R. 299, Nanango	B
..	4	Kandanga Creek	J
..	1	Kandanga Creek	J
..	1	Kandanga Creek	J
..	1	Kandanga Creek	J
..	1	Amamoor Range	I
..	1	Jimna Range	G
Mar. 19	1	Cooyar Creek (Mellera Creek)	C
..	1	Linville	C
..	1	Linville	C
..	1	Linville	C
..	1	Bluff Mountain	E
..	1	Bluff Mountain	E
..	1	Bluff Mountain	E
..	1	Conondale Range	G
..	2	Kandanga Range	K
..	1	Kandanga Creek	J
..	1	Amamoor Creek	I
..	1	Amamoor Creek	I
Apr. 5	1	Cooyar Creek	A & C
5	2	Cooyar Creek	A & C
5	1	Avoca Creek	A & C
6	1	Cooyar Creek	A & C
7	2	Taromeo Creek	A & C
..	1	Jimna Range	G
..	1	Jimna Range	G
..	1	Jimna Range	G
..	1	Kandanga Creek	J
May 22	1	Jimna Range	A
24	1	Kandanga Creek	A
24	39	Kandanga Range	A
..	1	Jimna Range	G
..	1	Conondale Range	G
..	1	Little Yabba Creek	H
..	1	Little Yabba Creek	H

FIELD SURVEY OF RED DEER—*continued*

Date	Number Sighted	Locality	Observer
June ..	1	Yabba Range	A
..	1	Yabba Range	A
..	1	Yabba Range	A
July 11	32	Cooyar Creek	C
..	3	S.F.R. 299, Nanango	B
Aug. ..	7	S.F.R. 299, Nanango	B
..	5	S.F.R. 299, Nanango	B
..	5	S.F.R. 299, Nanango	B
Nov. ..	2	Somerset Dam	F
Dec. ..	1	Somerset Dam	F
..	1	Yabba Creek	H
1957			
Jan. ..	1	Somerset Dam	F
Feb. 19	1	Cressbrook Creek	E
19	1	Cressbrook Creek	E
24	1	Stanley River	A
..	1	Monsildale	C
..	1	Cooyar	D
..	1	Blackbutt	D
Mar. ..	1	Biarra Range	E
..	1	Biarra Range	E
..	1	Biarra Range	E
..	1	Toogoolawah	E
..	1	Brisbane River	E
..	1	Brisbane River	E
..	1	Brisbane River	E
..	1	Brisbane River	E
..	1	Somerset Dam	E
..	1	Stanley River	E
Apr. ..	1	Little Yabba Creek	H
..	1	Little Yabba Creek	H
May 14	1	Cooyar	D
22	1	Little Yabba Creek	H
..	1	Crow's Nest	D
..	1	Crow's Nest	D
June 22	3	Elgin Vale	A
22	2	Elgin Vale	A
..	5	Conondale Range	G

(b) Dispersal

Red deer are well established in the mountain ranges encircling the headwaters of the Brisbane and Stanley Rivers, Cooyar and Emu Creeks, and the many tributaries (Figure 9). Populations are generally sparse (see Table 1), the larger being in areas where cleared grassy slopes, open forest and rain-forest are in close association (Figure 10).

Fig. 9.—Dispersal of red deer.

There is some evidence of a further gradual dispersal into Coast Range country, and westwards towards the Great Dividing Range.

(c) Other Observations

Red deer in Queensland (Figures 11 and 12) are either dark-brown, red-brown or grey-fawn. The calves are white spotted. Usually, adult shoulder height does not exceed 4 ft, and the only weight recorded was that of a pregnant hind at 202 lb. The antlers rise in an outward curve, rounded throughout, and heads with as many as 12 points were noted.

Fig. 10.—Typical red deer country near Cooyar Creek, April 8, 1956.

Fig. 11.—A red stag, Elgin Vale, February 2, 1957.

Fig. 12.—A red hind, Elgin Vale, February 2, 1957.

Seasonal behaviour is broadly outlined in Figure 13. Individual stags are in rut for about a month. During the roaring and rut season they rub their antlers on trees and shrubs, sometimes removing the bark of saplings from ground level to 6 ft up the trunks. In natural forests the species favoured as rubbing trees are blue gum (*Eucalyptus tereticornis* Sm.), grey ironbark (*Eucalyptus drepanophylla* F. Muell.), silver-leaf ironbark (*Eucalyptus melanophloia* F. Muell.), Moreton Bay ash (*Eucalyptus tessellaris* F. Muell.), pink bloodwood (*Eucalyptus intermedia* R. T. Baker), gum-topped box (*Eucalyptus hemiphloia* F. Muell.), wattle (*Acacia* sp.), Bunya pine (*Araucaria bidwillii* Hook.), dogwood (*Jacksonia scoparia* R. Br.), and forest oak (*Casuarina glauca* Sieb.).

In reafforested plantations a few pines (*Pinus patula* Schl. and Cham.), some 20 ft in height have been killed by similar rubbing. Deer also damage this species by browsing, particularly in dry seasons during the two years following planting. Although the percentage of trees affected is small, some replantings have been considered desirable.

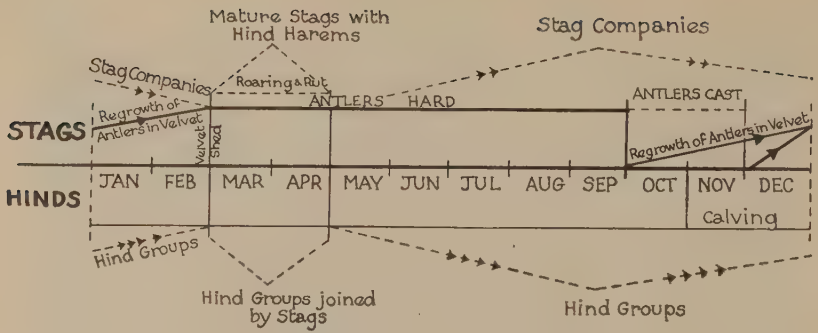

Fig. 13.—Seasonal behaviour of red deer.

On farmlands along the watercourses in the upper Brisbane Valley, deer feed on crops such as maize, oats, sorghum and lucerne.

Cattle tick, *Boophilus microplus* (Can.), was noted on three of the deer shot during the survey, but this phase of the investigation was not quantitative.

(d) Comments

The topography and land use, mostly pastoral, of the dispersal area are generally suited to red deer, and afford an appreciable amount of natural protection, but at the same time present difficulties in implementing some aspects of fauna conservation such as the prevention of all illegal shooting. That such shooting has occurred is supported by considerable circumstantial evidence, and the existence of antler trophies.

This deer country includes a number of fauna sanctuaries (State forest reserves and some private lands), a factor which complicates the formulating of an open season hunting policy which would adequately protect deer and not adversely affect the interests of farmers, foresters, graziers and sportsmen.

To date, controlled shooting has given reasonable satisfaction as a method of controlling red deer as pests.

V. RUSA DEER

(a) Importation and Releases

In 1912 this species was brought from the Celebes and the Moluccas to Friday Island in Torres Strait by Mr. R. A. C. Hockings, of Thursday Island. The animals thrived and some years later were found on the nearby and much larger Prince of Wales Island. About 1914 some were transferred to Possession Island (Figure 14). Reports that rusa deer are on the mainland have not been confirmed. (In 1952 four stags and three hinds were liberated on North East Island, Northern Territory).

(b) Comments

The sizable herds on these islands were decimated by troops during World War II.

VI. GENERAL CONCLUSIONS

The results of this survey and other field observations indicate that the present populations and distributions of fallow, axis and rusa deer do not warrant and would not support a policy of open season hunting. Red deer offer possibilities in this regard, but before implementation could be considered, well defined and adequately staffed management areas would be required.

Fig. 14.—Distribution of rusa deer.

VII. ACKNOWLEDGEMENTS

These investigations were facilitated by the following and their assistance is gratefully acknowledged:—Messrs. E. Duncan (Forest Ranger, Nanango), E. Bishop ("Swansdown", Linville), E. Clarsen (Upper Freestone), W. Dempsey (Freestone), T. Aikin ("Pine Creek", via Stanthorpe), E. C. Clarke ("Maryvale", via Charters Towers) and H. N. Hockings (Thursday Island).

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(Received for publication October 5, 1959)

TECHNICAL NOTES

CABBAGE PEST CONTROL INVESTIGATIONS, 1954

Cabbage (*Brassica oleracea* var. *capitata* L.), cauliflower (*B. oleracea* var. *botrytis* L.) and related crops form a large part of vegetable plantings in south-eastern Queensland during autumn, winter and spring. There have been few instances where marketable crops have been harvested without some form of insect control, and attention to pests has become routine.

Important insect pests are cabbage white butterfly, *Pieris rapae* L., cabbage moth, *Plutella maculipennis* Curt., and cabbage centre-grub, *Hellula undalis* (F.); pests of minor importance are cabbage aphid, *Brevicoryne brassicae* (L.), and cabbage leaf-miner, *Liriomyza cruciferarum* Her.

Comparison of 1954 Control Programmes

A comparison was made of control programmes in common use at March 1954. Early Allhead variety of cabbage, planted 1 ft 6 in. apart in rows spaced 2 ft 6 in. apart at Redlands Experiment Station, Ormiston, was used as test material. Two 6 x 6 latin squares were laid out, using plots of 24 plants in two adjacent rows of 12 plants. No guard rows were used. Treatments were applied six times at fortnightly intervals to an infestation of cabbage centre-grub, cabbage white butterfly and cabbage moth. Data obtained were bulked for analysis (Table 1).

In this trial, cabbage centre-grub, which is usually less important than cabbage white butterfly and cabbage moth, was the most important species present. Dieldrin (0·1 per cent. active ingredient) and DDT (0·1 per cent. active ingredient) sprays, and the BHC/DDT dust, gave satisfactory control of this pest and also of light infestations of cabbage white butterfly and cabbage moth. Rotenone and BHC (0·03 per cent. active ingredient) gave unsatisfactory control.

Screening of Newer Insecticides

A screening trial was carried out later in 1954 to give information on efficacies of newer insecticides for general cabbage pest control, using an established infestation of cabbage white butterfly and cabbage moth on cabbage plants six weeks after transplanting. The cabbages were Succession variety and were planted in late September 1 ft 6 in. apart in rows spaced 2 ft apart at the Queensland Agricultural High School and College, Lawes. Nine treatments replicated six times were applied, using single-row plots of 20 plants arranged in a randomized block layout. On completion of the screening test 14 days after treatment, a fortnightly treatment programme was maintained to determine whether economic control was possible in such circumstances. Total plant damage at harvest was assessed by assigning plant damage to one of six categories, 0–5, as shown in Figure 1.

Table 1

COMPARISON OF CONTROL PROGRAMMES IN USE AT MARCH, 1954

Treatment		Larvae per Plant 4 Weeks from Planting (Immediately prior to 3rd treatment)				Harvest Data—Marketable Heads		
		H. undalis		*P. rapae*	*P. maculipennis*			
Material	Concentration†	Transformed Mean*	Mean	Mean	Mean	Number per Treatment (288)	Weight per Treatment	Average Days to Harvesting
DDT plus BHC dust	2·00 DDT 0·26 BHC	0·86	0·014	0·012	0	274·8	1,135·2	70·9
Rotenone dust	0·45	5·78	1·410	0·033	0·175	153·6	616·8	77·8
BHC emulsifiable concentrate ..	0·03	4·43	0·819	0·054	0·012	184·8	770·4	74·2
DDT emulsion concentrate ..	0·1	0·90	0·020	0·092	0·008	264·0	1,046·4	72·2
Dieldrin emulsifiable concentrate	0·1	0·99	0·028	0·049	0·008	273·6	1,123·2	71·4
No treatment		6·15	1·583	0·833	1·075	34·8	129·6	78·3
Differences necessary for significance	·05	·86	..	Not analysed		26·4	108·0	2·7
	·01	..	..			36·0	144·0	3·7

* $\sqrt{24x + \frac{1}{2}}$.

† % active w/v (dusts); % active w/w (concentrates).

Table 2

SCREENING OF MATERIALS FOR CABBAGE PEST CONTROL

Data from the screening trial are presented in Table 2.

Treatment		Screening Data						Harvest Data			
		P. rapae			*P. maculipennis*			Average Number of Larvae per Plant		Average Damage Rating (0–5)	Percentage of Marketable Cabbages
Material	Concentration*	Pre-treatment	Post-treatment		Pre-treatment	Post-treatment					
		Average Number of Larvae per Plant†	Percentage of Pre-treatment§		Average Number of Larvae per Plant	Percentage of Pre-treatment§		*P. rapae*	*P. maculi-pennis*		
			3–4 days‡	13–14 days		3–4 days	13–14 days				
DDT emulsion concentrate	0·1%	1·68	1·6	6·2	1·33	0	12·0	5·03	0·62	2·78	87·5
BHC emulsifiable concentrate	0·03%	1·15	0	1·5	1·33	0	6·5	2·16	0·33	1·75	96·7
DDT plus BHC dust ..	2·0% DDT 0·26% BHC	1·48	20·4	43·5	1·13	9·7	20·5	3·11	0·45	2·22	91·5
Lead arsenate dispersible dust	1¼ lb to 50 gal	1·58	22·6	44·0	0·93	11·8	107·5	1·99	16·33	3·25	15·8
DDT dispersible dust ..	0·1%	1.62	16·2	28·0	0·97	24·4	52·6	1·81	0·43	1·77	93·2
Dieldrin emulsifiable concentrate	0·05%	1·78	2·3	6·8	1·32	1·2	15·4	4·50	0·24	1·83	91·2
Endrin emulsifiable concentrate	0·025%	1·57	0	1·1	0·98	3·2	1·5	0·97	0·36	0·85	97·5
No treatment		1·97	121·3	95·7	1·28	106·0	114·6	1·65	> 19·50	(4·58)	(4·2)
Differences necessary for significance	0·05 0·01	Not analysed			Not analysed			Not analysed		·65 ·85	No sig. diff.

* Percentages are w/v active ingredient (dusts) and w/w active ingredient (concentrates).

† 1 in. rain and 1 in. irrigation from 1st to 3rd days.

‡ 0·30 in. rain plus hail on 4th day; 3·50 in. rain on 8th day.

§ Treatment percentages adjusted for variations in populations receiving no treatment.

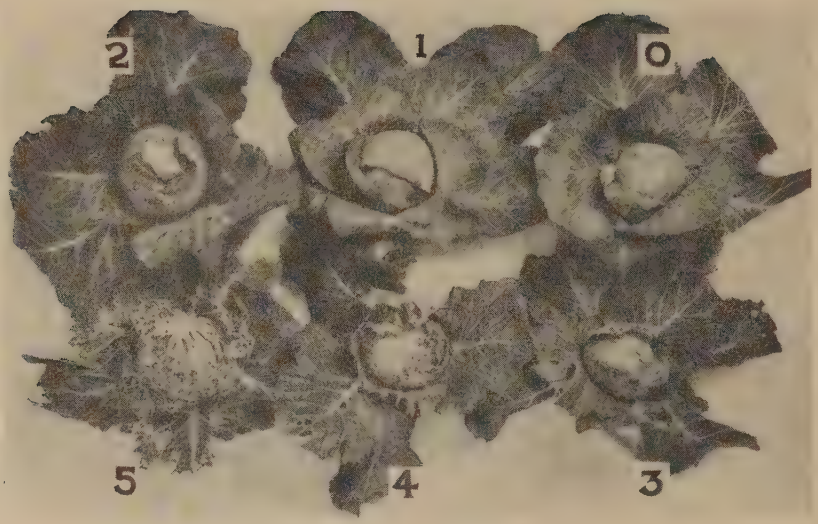

Fig. 1.—Damage ratings of cabbage at harvest.

Sprays containing endrin emulsifiable concentrate at 0·025 per cent. active ingredient, dieldrin emulsifiable concentrate at 0·05 per cent. active ingredient, BHC emulsifiable concentrate at 0·03 per cent. g.i., and DDT dispersible powder at 0·1 per cent. active ingredient proved the superior treatments, and endrin was the most efficacious in all factors considered.

Concentration-level Trials

To determine optimum concentrations of endrin and dieldrin as an alternative to established treatments, a concentration-level trial was laid down in the spring of 1954 at Redlands Experiment Station on a block of Early Allhead cabbage planted 1 ft 3 in. apart in rows spaced 2 ft apart. Eleven treatments replicated five times were arranged on 8-plant single-row plots in a randomized block layout; each datum row alternated with an untreated row. Pest species prevalent were cabbage white butterfly, cabbage moth and cabbage leaf miner. To assess leaf-miner infestation, six categories of mine prevalence were raised. Of these, the first three only were used. They were 0 = no damage; 1 = few mines on older leaves; and 2 = older leaves mined and few mines on new leaves.

Data obtained are presented in Table 3.

To confirm the efficacy of endrin in cabbage pest control, a concentration-level trial was carried out comparing endrin treatment with the then standard BHC/DDT dust treatment on a yield basis. Enkhuisen Glory variety of cabbage, planted 1 ft 6 in. apart in rows spaced 2 ft 6 in. apart at Redlands Experiment

Table 3

CONCENTRATION-LEVEL DETERMINATION FOR DIELDRIN AND ENDRIN

Treatment		Larvae per Plant—Post-treatment†						Mean Damage Rating per Plant—Post-treatment		Overall Mean Damage Rating per Plant
		P. rapae			*P. maculipennis*			*L. cruciferarum*		
Material	Concentration‡	14 days		21 days	14 days		21 days	14 days	21 days	
		Transformed Mean*	Mean	Mean	Transformed Mean*	Mean	Mean			
DDT plus BHC emulsifiable concentrate	0·1 DDT 0·03 BHC	1·81	0·375	0·2	1·17	0·15	0·2	1·6	1·8	1·275
DDT plus BHC dust	2·0 DDT 0·26 BHC	1·61	0·275	0·4	1·43	0·25	0·2	1·6	1·8	2·65
Dieldrin emulsifiable concentrate	0·1	2·23	0·625	0·2	0·81	0·025	0·2	0·6	0·8	0·45
Dieldrin emulsifiable concentrate	0·075	1·78	0·375	0·2	1·09	0·10	0·4	0·4	0·2	0·575
Dieldrin emulsifiable concentrate	0·05	1·55	0·25	0·2	1·09	0·075	0·4	0·6	1·0	0·975
Dieldrin emulsifiable concentrate	0·025	2·11	0·55	0·4	1·04	0·075	1·0	0·8	1·8	2·05
Endrin emulsifiable concentrate	0·05	1·81	0·375	0·2	1·22	0·20	0·4	0	0·2	(0)
Endrin emulsifiable concentrate	0·0375	1·49	0·275	0	1·04	0·0125	0·2	0·2	0	(0)
Endrin emulsifiable concentrate	0·025	1·96	0·55	0	1·35	0·275	0	0·2	0·6	(0·075)
Endrin emulsifiable concentrate	0·0125	1·86	0·45	0·2	1·04	0·075	0·2	1·0	1·0	0·525
No treatment			(4·70)	5·6			2·71	2·0	2·0	5·00
Differences necessary for significance	0·05	0·85		Not analysed	0·67			Not analysed		0·59
	·01				0·90					0·80

* $\sqrt{8x + \frac{1}{2}}$.

† No pre-treatment infestation.

‡ % active w/v (dusts); % active w/w (concentrates).

Table 4

ASSESSMENT OF ENDRIN CONTROL PROGRAMMES

Treatment		Larvae per Plant												Mean Value of Infestation Rating		
		P. rapae						*L. marulipennis*						*L. cruciferum*		
		5 days		22 days		29 days		5 days		22 days		29 days				
Material	Concentration‡	Transformed Mean*	Mean	Transformed Mean†	Mean	Transformed Mean*	Mean	Transformed Mean*	Mean	Transformed Mean*	Mean	Transformed Mean*	Mean	5 days	22 days	29 days
Endrin emulsifiable concentrate ..	0·05	6·06	1·85	29·4	0·46	3·40	0·59	5·85	1·73	5·15	1·39	3·64	0·66	2·0	1·2	0·1
Endrin emulsifiable concentrate ..	0·025	6·06	1·85	40·9	0·85	5·82	1·78	5·78	1·70	5·58	1·60	4·30	0·94	2·0	1·0	1·0
Endrin emulsifiable concentrate ..	0·0125	6·19	1·94	40·1	1·18	6·04	1·89	6·12	1·90	6·22	2·10	4·28	0·925	2·0	1·2	1·0
DDT plus BHC dust	2·0 DDT 0·26 BHC	6·21	1·94	46·6	1·43	7·04	2·63	5·93	1·76	5·68	1·68	4·06	0·84	2·0	1·2	1·0
No treatment ..		6·46	2·10	46·1	1·06	9·59	4·60	6·06	1·85	13·35	8·94	6·85	2·35	2·0	1·6	2·0
Differences necessary for significance	0·05	·72		20·4		2·11		1·09		1·16		·54		Not analysed		
	0·01	1·0		29·0		2·95		1·53		1·62		·75				

Larvae counts and infestation ratings given at various days after transplanting.

First treatment on 6th day, second on 23rd day after transplanting.

* $\sqrt{20x}$

† $\sqrt{\frac{1}{\sin e\ 20x}}$

‡ % active w/v (dusts); % active w/w (concentrates).

Station in mid-October, was used. Five treatments replicated four times were applied at fortnightly intervals against a pest complex of all major species. Each plot contained 20 plants in two adjacent rows of 10 plants.

Relevant data are presented in Tables 4 and 5.

Table 5

HARVEST DATA FOR ENDRIN CONCENTRATION-LEVEL TRIAL

—	Endrin Emulsifiable Concentrate			DDT/BHC Dust	No Treatment	Differences Necessary for Significance	
	0·05%	0·025%	0·0125%			0·05	0·01
Mean damage rating per plant	0·20	0·63	0·59	1·10	(5·00)	·35	·51
Number of marketable heads per treatment (max. 80)..	80	77	77	76	0	Not analysed	
Weight of marketable heads per treatment (lb) ..	436·0	392·0	377·6	361·2	(0)	84·8	122·0
Average weight of marketable heads (lb)	5·45	5·09	4·90	4·70	0	Not analysed	
Weight of unmarketable cabbages per treatment (lb)	0	4·8	5·2	11·2	141·6	Not analysed	
Endrin residues 7 days after last treatment (p.p.m.)—							
External leaves ..	4·3	3·5			6·0		
Internal leaves ..	3·0	2·0			5·5		

The minimum satisfactory concentration of endrin was determined in the first concentration-level trial as 0·025 per cent. active ingredient (Table 3), and this was confirmed in the final yield trial (Table 4). Dieldrin did not prove a satisfactory alternative material.

Conclusion

From the data obtained in these trials, endrin emulsifiable concentrate as a spray at a concentration of 0·025 per cent. active ingredient applied at fortnightly intervals from transplanting was deemed to be the best replacement for the BHC/DDT dust included in control programmes. Recommendation of this treatment recognized prevention of infestation as the basic requirement for this type of pest control.

Further work has been undertaken to determine the status of endrin in aphid control and the suitability of more recently developed materials as substitutes or replacements for endrin.

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(Received for publication August 13, 1959)

BENZENE HEXACHLORIDE IN PINEAPPLE FIELDS

Scarabaeid larvae have been found associated with root damage to pineapple plants in various coastal localities in Queensland. Where a recommendation of BHC in the soil as a control method might reasonably have been made from work on other crops in the same localities, a consideration of possible tainting of the fruit has prevented this.

The extent to which tainting of pineapple fruit follows spraying and dusting of plants has been determined (Brimblecombe 1955). The present work was designed to investigate the effects of soil applications.

The trial was carried out on a contoured double-row of pineapples at the Maroochy Experiment Station near Nambour, between October 1957, and September 1959. The soil was a grey-brown loam. Plots of 14 ft of double-row, each containing 30 plants, were used in a 4 x 4 randomized layout. At rates shown in Table 1, 10 per cent. B.H.C. dust (1·3 per cent. gamma isomer) was applied to the plant bed shortly before planting, and worked in. The 10 in. bands of insecticide were placed between and to each side of the plant row positions and spaced 14 in. apart.

Ripe fruit were harvested and each was submitted to a panel varying from six to 11 tasters for opinions on tainting, which was recorded as absent, slight, or objectionable. The results are presented in Table 1.

Table 1

SUMMARY OF OPINIONS ON TAINTING

Rate per Acre of Application of 10% BHC (lb)	No. of Fruit	Mean No. of Opinions per Fruit	Percentage of Fruit with at Least One Opinion Indicating Taint	Percentage of Opinions Indicating any Taint	Percentage of Opinions Indicating Objectionable Taint
0	25	8·8	75	26·9	1·4
56	34	8·0	62	28·3	3·3
112	29	8·7	62	13·4	1·9
168	38	8·6	55	13·2	1·6

The opinion of panel members could have been influenced by the degree of fruit maturity and by the low sugar/acid ratio of winter fruit. It is apparent from the results, however, that BHC as preplanting soil applications at the rates used did not introduce taints or off-flavours into the plant crop. This finding is supported by those instances where BHC has been used in commercial plantings: invariably no market rejections have followed.

No differences in plant growth were observed at any stage.

REFERENCE

BRIMBLECOMBE, A. R. (1955). Pineapple scale investigations. *Qd J. Agric. Sci.* 12: 81-94.

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(Received for publication November 9, 1959)

S. G. REID, Government Printer, Brisbane